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Price Impacts of Deals and Predictability of the Exchange Rate Movements

Takatoshi Ito and Yuko Hashimoto

6.1 Introduction

The overwhelming majority of the spot foreign exchanges are now transacted through the global electronic broking systems—EBS and Reuters D3000.[1] This contrasts to the situation fifteen years ago, when brokers in the interbank market were mostly human and direct dealings between dealers also had a substantial share in the spot market. The euro/dollar and dollar/yen are the key currency pairs that traded on EBS, whereas Reuters has strengths in transactions of sterling/dollar, CAD/dollar, AUD/dollar, and NZD/dollar.

The EBS system works as follows.[2] A bank dealer places a "firm" limit order, either ask or bid, with specified price and units that the dealer is ready to trade if hit. A member bank sets credit limits to each of the possible trading partners in the EBS system when it joins the system. The

1. For papers that use electronic broking systems, see Goodhard, Ito, and Payne (1996), Goodhart and Payne (1996), Berger et al. (2005) and Chaboud et al. (2004).

2. Details of the EBS system and characteristics of the data are explained in Ito and Hashimoto (2004).

credit/counterparty risk is controlled by the EBS computer automatically. The computer collects these orders and displays on the screen of each member the following information, "best ask," "best bid," "best ask for the member," and "best bid for the member." The former two do not necessarily agree with the latter two, respectively, because the EBS system controls for the bilateral credit lines and shows the best available for each institution. Hence, if the member does not have a credit line with the market maker(s) that is (are) posting the "best" ask/bid in the market, then the individually available best quotes deviate from the market best quotes. The computer continuously clears the order whenever the sell and buy order matches at the same price—this could happen either when a buyer hits the ask quote posted in the system, or a seller hits the bid quotes posted in the system. The electronic broking system is a centralized network of traders. In a sense, the electronic broking system can be regarded either as a collection of large numbers of market makers or as a continuous (Walrasian) auctioneer. We will use the dollar/yen and euro/dollar data sets provided by EBS.[3]

Retail customers place their buy or sell orders via banks, based on their private information. Then, banks transmit those customers' orders to the electronic broking system. Banks may add their own proprietary trading positions onto the customer orders. As the trading system is highly computerized, trading strategies of banks have evolved too. Until several years ago, bank dealers who received customers' orders were allowed by bank policy to hold their own proprietary positions for profit-taking. They tended to add their own positions when they executed the customers' orders if they felt that customer' orders contained some valuable information. Receiving customers' orders meant a special information advantage in forecasting the direction of the foreign exchange rate. See Lyons (1995, 1996, 1997, 1998, 2001) for modeling of this line of reasoning. In line with the information and pricing in market, Lyons and Moore (2005) applied the information model to the transactions in a triangle of markets, USD/JPY, EUR/USD, and EUR/JPY and found the transaction affected prices.

Dealers in banks now have only very small amounts of their own proprietary positions. Responsibility of proprietary trading has been shifted to an independent department, sometimes characterized as an in-house hedge fund. A proprietary trading section uses more computer modeling than private information extracted from customers' trading. Speeding millions of dollars on programmers (often physics PhDs) and high-speed computers is necessary for high-frequency trading strategy. Clearly they see profit opportunities by betting on directions of the exchange rate in the very short-run, that is, a few minutes to several hours.

In contrast, many economists still believe that the exchange rate is basi-

cally a random walk, and it would be a profitless effort to conceive a model that can predict an exchange rate movement. The gap between the academic random walk and millions of dollars invested for a bet on predictable movements in the real world is remarkable, as pointed out by Ito (2005a, b). Evans and Lyons (2005a), for example, examine daily Euro/USD exchange rate returns based on the trades by the end-user and find a persistent (days) effect in currency market induced by news announcement. Still, it is our view that foreign exchange rate modeling in the academic literature is lagging behind the reality.

Conventional wisdom in the academic literature is that the exchange rate follows a random walk for frequencies less than annual, that is, daily, weekly, or even monthly, whereas it shows some time trends, cyclicality or in general history dependence at lower frequencies. For example, Evans and Lyons (2005b) show forecasting performance of a microbased model against a macro and a random walk model using end-user exchange rate. Some studies in the microstructure focuses on very high frequency movements of the exchange rate and show that the exchange rate may respond to pressures of customers' orders. Evans and Lyons (2002), for example, reported a positive relation between daily exchange rate returns and order flows for deutsche mark/dollar. Berger and colleagues (2005) also showed a positive contemporaneous relationship between order flows and the exchange rate, while they reported no evidence of the predicting power of order flows for future exchange rate. In Evans and Lyons (2005c), heterogeneity of order flow was considered in estimating the price impact. Based on the end-user order flow data, they show order flow provides information to market makers.

In this paper, we will examine the relationship between pressures of seller-initiated orders or buyer-initiated orders and the resulting price movements in the following few minutes to half an hour. Although direct observations of customer order flows to banks are not available, deals initiated by sellers and those by buyers in the EBS system are observable. Order flows and executed prices give the information on customers and bank proprietary desks.

Given the organizational change in creating proprietary trading departments in banks, customer orders have to contain both retail customers and bank proprietary positions. Retail customer orders contain information, but orders from computer-generated programs in an in-house proprietary trading department are equally important. It is best to exact information of order flows from seller-initiated and buyer-initiated deals in the system. Therefore we take actual deals done in the market as the buying or selling pressures in the market.

The EBS data record the ask-side deals or bid-side deals for every second. (Lowest given or highest paid are recorded for each second, when at least one deal on either side was executed during the second.) An ask-side deal

means that the ready-to-sell quote was hit by a buyer, thus it represents a buyer-initiated deal, that is, a piece of buying pressure. A bid-side deal means that the ready-to-buy quote was hit by a seller, thus it represents a seller-initiated deal, that is, a piece of selling pressure. Therefore, by taking the difference between the number of ask-side deals and the number of bid-side deals in the time frame of x minutes, we can quantify the buy pressure or sell pressure during the x minutes. Then we will measure an impact of buy (sell) pressure to drive up (down) the price contemporaneously or with lags.

The EBS data were exploited in two papers written by Federal Reserve Board economists. Chaboud and colleagues (2004) analyzed the relationship between a macro news announcement and trade volume, and found news releases tend to raise trade volume. Berger and colleagues (2005) showed the correlations between order flows and exchange rate movement. The trading volumes of the buyer-initiated trades (ask-side deals) in excess of the seller-initiated deals (bid-side deals) are considered to be order flows. They examined whether the exchange rate appreciates if there are more buyer initiated trades in several time aggregations, one minutes, five minutes, ten minutes, one hour, and one day. They find strong association of order flows and exchange rate changes, namely, an excess of buyer-initiated trades is associated with a rising price. The contemporary association is strongest in the shortest horizon. Although Berger and colleagues (2005) find a positive contemporaneous price impact of order flow, they argue that there is little evidence for predictability, namely lagged trades impacting on the price change in the next minute.

The objective of our paper is to analyze the forecasting power of order flows (actual deals in the preceding thirty minutes) on future exchange rate movements at various frequencies: one-, five-, fifteen- and thirty-minute windows. The data used in the analysis is extracted from the EBS spanning from January 1999 to October 2003. Our measure of order flows is the "net ask deals" that is defined as the difference between the number of ask deals and bid deals. In our paper, "deal" in one minute is the number of seconds in which at least one deal was done. Although this is not precisely the trading volumes, it is a close substitute.[4]

The prices used to calculate exchange rate returns are based on actual transaction prices, not quoted prices (bid or ask) which may not represent market clearing prices—this is the same as Berger and colleagues (2005) and Chaboud and colleagues (2004). We then estimate price impact of deals in the following time periods up to thirty minutes.

We find strong evidence that order flows (deals) have prediction power for the price movement of one minute to five minutes, while thirty minutes is found to be too long for prediction. The degree of price impact is found

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4. Berger et al. (2005) and Chaboud et al. (2004) use the actual volume data, but the use of the data is restricted in the central bank community.

to diminish over time, although intervention may induce lagged price impact, and there may be an adjustment process in exchange rate movements.

The rest of this paper is organized as follows: In section 6.2 we describe the data. Section 6.3 shows the estimation model and reports the results. Section 6.4 concludes the paper.

6.2 Data[5]

The data set includes information of quote prices and deal prices of the dollar/yen and the euro/dollar currency pairs. The sample period is from January 4, 1998 to October 31, 2003 for USD/JPY, and from January 3, 1999 to October 31, 2003 for EUR/USD.[6] It contains information for, among others, best bid, best ask, deal prices done on the bid side (lowest given), and deal prices done on the ask side (highest paid).[7] It does not contain any information on the volume associated with bid, offer, or deal, or any information on the identity of bid, ask, or deal. The EBS global system consists of three regional computer sites, based in Tokyo, London, and New York, and each region covers Europe, North America, and Asia, respectively. The system matches orders either within the site or across different sites.

We exclude all data from Friday 22:00 (GMT, winter, 21:00 in summer) to Sunday 21:59 (GMT, winter, 20:59 in summer, respectively). If at least one of the three major markets has a national (banking) holiday, then that day is dropped from the sample. In addition, if there is no trade recorded in the time window of the frequency, that particular time is dropped.

To analyze returns at various frequencies, we use the last deal price of the time interval. For the x-minute frequency, we use the last deal price within the x-minute window ($x = 1, 5, 15, 30$). The number of bid and ask deals are separately counted within each frequency. For example, the number of bid deals in 5-minutes equals the total number of seconds in which one or more deals took place.

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5. The authors are grateful to EBS for providing a proprietary data set for this academic purpose and to EBS analysts in New York for guidance on the nature of the data.

6. Data are of the 1-second time slice. The system records, at every second, bid, offer, deals that are posted and carried out in the world-wide EBS system. Bid and offer rates are recorded at the end of time slice. For example, bid and offer rate at xx hour, yy minute, zz second. Fluctuations of the bid and offer rates within the second (in the time slice) are not recorded and cannot be inferred. It is theoretically possible that bid and offer rates move up and down within the second, but not shown in the data set. Deal rates are recorded on the basis of Highest Paid and Lowest Given at the 1-second time slice. See Ito and Hashimoto (2004, 2006) for details.

7. The deal (on either side) recorded at zz second includes those that took place between zz – 1 second to zz second. When there are multiple trades within one second, "lowest given price" and "highest paid price" will be shown. A highest paid deal means the highest price hit (done) on the ask side within one second and the lowest given deal means the lowest price hit (done) on the bid side within one second.

The *ask quote* means that the institution with the quote is ready to sell (the dollar in exchange for the quoted yen) and the *bid quote* means that the institution with the quote is ready to buy (the dollar in exchange for the quoted yen). When the deal is done at the ask side—we call it *ask deal*—it means that the ask quote is *hit* by a buyer. When the deal is done at the bid side—we call it *bid deal*—it means that the bid quote is hit by a seller. Therefore the ask deal is a buyer-initiated deal, and the bid deal is a seller-initiated deal, according to the description in Berger and colleagues (2005).[8]

By counting the number of ask (bid) deals within a fixed time period (x-minutes), we measure the order flows to buy (or sell, respectively). If the number of the ask deals is larger (smaller) than the number of the bid deals in the time period, it is interpreted that pressure to buy (or sell, respectively) is stronger. When pressure to buy (sell) is stronger, the prices—here the price of the dollar in terms of the yen—tend to rise (or drop, respectively). There are two ways that pressure is materialized into quote and price changes. First, when buy orders hit all volumes at the best ask quotes, then the second best ask quotes becomes the best, and the best ask moves up. Second, by watching that deals are done on the ask side, dealers may withdraw the best ask quote and requote at a higher price. Either way, the ask quote tends to move up when buyers start to hit the best ask quote. If the process continues, then the ask deal prices continue to move up in the subsequent time period. The reverse is true; if selling pressure is strong, then bid deal prices may decline. When the ask quote is rising, the bid quote is likely to rise with it as dealers revise the equilibrium value of the currency.

The above inference leads to a hypothesis that the return of (or changes in) the ask deal price, as well as ask quote price, will be influenced by the buy pressure, while the return of the bid deal price, as well as bid quote price, will be influenced by the sell pressure.

As we differentiate ask-side deals (buy pressure) and bid-side deals (sell pressure), we can identify the direction of order flows from deal data. So, our variables, the difference between the ask-side and bid-side deals, are regarded to represent order flows.

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8. The buyer-initiated trades (the seller-initiated trades) used in Berger et al. (2005) corresponds to the number of deals on ask side (the number of deals on bid side) in our chapter, respectively. The order flow, the net excess of buyer-initiated trades in Berger et al. corresponds to the *netdeal* in our chapter. Berger et al. had access to the data of actual transaction volumes—proprietary data of EBS—while we use the number of seconds in which at least one deals was done. The number of deals, rather than the signed (actual) volume, is good enough proxy for the volume of transaction. In fact, the actual transaction volume is not revealed to participants other than parties involved, so that they would not be able to be used in prediction of price movement in real time.

USD/JPY — Ask — Bid

Buy pressure raises ask price by knocking off quotes

Buy pressure may raise bid price too

USD/JPY — Ask — Bid

Sell pressure drives down bid price by knocking off quotes.

Sell pressure may drive down ask price too
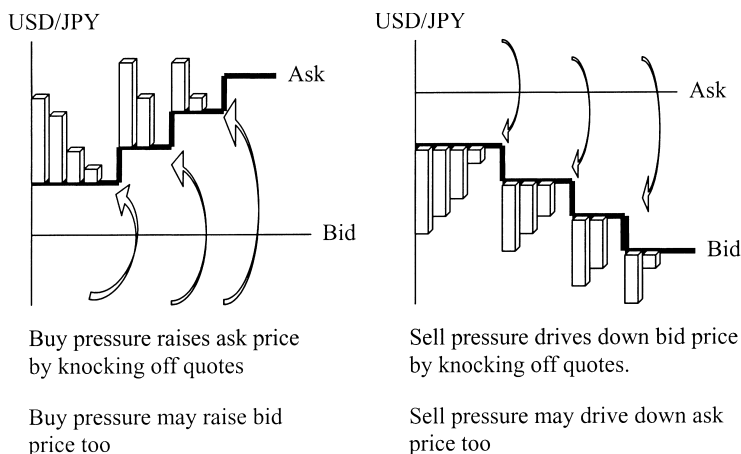
Fig. 6.1   Stylized process of one-sided deals knocking off best quotes

6.3   Prediction Window Estimation

In this section, we examine whether order flows in period t will have a predictive power of price movement from period t to $t + 1$. More precisely, we examine whether a relative number of deals on the bid and ask side will drive the price lower or higher x-minute(s) later. For the proxy of order flows in the EBS data, we use *net deals,* defined as the difference between the number of ask deals and that of bid deals during a specified frequency. For testing the predictability of this framework, we use three frequencies: 1-minute, 5-minute, 15-minute and 30-minute windows. The sample period covers from January 4, 1998 to October 31, 2003 for USD/JPY, and from January 3, 1999 to October 31, 2003 for EUR/USD pair.

We will examine *netdeals* at period t to help predict the price movements in period $t + 1$. A similar attempt was made by Berger and colleagues (2005). They regarded a net excess of buyer-initiated trades as order flow. The *net excess of buyer-initiated trades* is the difference between the volume of the buyer-initiated trades, or deals done on the ask side, and the seller-initiated trades, or deals done on the bid side. They note that a dealer tends to break up a large customer's order into small lots and execute them in a staggered manner, in order to avoid large impacts on prices.

One difference of our approach from Berger and colleagues (2005) and Evans and Lyons (2002) is that we do not include contemporaneous effect in this inference, in order to avoid an endogeneity problem, and to test predictability directly.

A variable *netdeal* corresponds to net excess buyer-initiated trade, as a proxy for order flow. We also use a *netdeal ratio* (*ndr*), or the *netdeal* over

the total number of deals (both bid and ask sides) during the period, instead of *netdeal*. Since the overall market activity varies from time to time, the share is able to scale *netdeal* by the degree of market activeness. For example, if # *deal ask* = 700 and # *deal bid* = 690 when the market is active and # *deal ask* = 80 and # *deal bid* = 70 when the market is calm, then *netdeal* is 10 for both cases but *ndr* is 0.0072 and 0.067, respectively.

Therefore, the two definitions of order flows are written as follows:

$$netdeal = \text{\# } askdeal - \text{\# } biddeal$$

$$ndr = \frac{\text{\# } askdeal - \text{\# } biddeal}{\text{\#} askdeal + \text{\# } biddeal}$$

To reiterate, a conjecture of deal and price movements is as follows: When *ndr* is positive it represents buying pressure, and when *ndr* is negative it represents selling pressure. We expect that buying pressure will raise the ask quote, as explained earlier, and selling pressure will lower the bid quote. Therefore, we construct a variable that would represent buying pressure and selling pressure separately in order to associate with ask- and bid-quote movements separately.

Let us define the buying pressure and the selling pressure as follows, respectively:[9]

$$nd_t^{plus} = \max(netdeal_t, 0), \text{ and}$$

$$nd_t^{minus} = \min(netdeal_t, 0)$$

The regression model is specified as follows. We examine whether deals done at period $t - 1$ at either side help predict the price movement for the next period, t, using information that is contained in the data up to period t:

$$(1) \qquad \Delta s_t = \beta_0 + \beta_1 nd_{t-1}^{plus} + \beta_2 nd_{t-1}^{minus} + \sum_j \delta \Delta s_{t-j} + \varepsilon_t,$$

where Δs denotes the exchange rate return from period $t - 1$ to t. Here, nd^{plus} means that the number of deals done at the ask side is larger than the number of deals done on the bid side during period t, and nd^{minus} vice versa.

The estimation methodology is similar to that of Berger and colleagues (2005), in which they estimated the contemporaneous regression with time horizons of 1-minute, 5-minutes, 10-minutes, 1-hour, 1-day, and 1-month. They went on to estimate another regression with lagged Δs and order flows up to five periods. In this paper, we estimate equation (1) with various definitions of returns and explanatory variables.

In the estimation, six different definitions of returns are used for this variable. For deal-price returns we consider the following three patterns:

9. Summary statistics of nd^{plus} and nd^{minus} are summarized in Appendix tables, A-1 and A-2.

the midpoint of the deal-ask and deal-bid prices, the ask-side deal price, and the bid-side deal price. For quote returns, we again consider the three types of returns: the midpoint of the quote prices, the ask price, and the bid price. Berger and colleagues (2005) use the midpoint of the ask- and bid-deal prices, which is a standard practice in the literature. However, the midpoint may not represent a true state of the market, if the last ask side deal was done several minutes prior to the last bid deal. In other words, when the market is thin or one-sided (strong buy pressure or sell pressure) then the midpoint may not be representative. Therefore, we also use the bid-bid return and ask-ask returns, in addition to the midpoint price returns.

Therefore, the regression models to be estimated are the following:

(2) $\quad \Delta s(askdeal)_t = \alpha_0 + \alpha_1 nd_{t-1}^{plus} + \alpha_2 nd_{t-1}^{minus} + \sum_j \delta \Delta s_{t-j} + \varepsilon_t$

(3) $\quad \Delta s(biddeal)_t = \beta_0 + \beta_1 nd_{t-1}^{plus} + \beta_1 nd_{t-1}^{minus} + \sum_j \delta \Delta s_{t-j} + \varepsilon_t$

(4) $\quad \Delta s(midpoint)_t = \gamma_0 + \gamma_1 nd_{t-1}^{plus} + \gamma_2 nd_{t-1}^{minus} + \sum_j \delta \Delta s_{t-j} + \varepsilon_t$

In equation (2), the parameters α_1 captures the direct price impact of ask-side transactions (buy pressures) on the ask-deal price (sell quote) movement. The continuum of ask deals will drive up the price in the following period (dollar appreciation) after eating up orders at the best-ask price and requoting of ask-side dealers. The expected sign is unambiguously positive. The parameter α_2 shows the effect of bid-side deal on the ask quotes in the following period. The expected sign is positive since the negative movement (selling pressure) will drive down the prices. But the effect may not be as significant as α_1 since the causal effect of deals on quotes is not as direct as the ask side deals. If the value of α_1 equals that of α_2 then the effect is symmetric and there is no reason we differentiate nd^{plus} and nd^{minus} but, to use $netdeal$ suffices.

In equation (3), the parameter β_2 shows the price impact of bid-side transaction (sell pressures) on bid-price (buy price) returns. Enough bid deals will drive down bid quotes in the following period, knocking-off orders at the best bid price and causing quote revisions on the bid side. The β_2 is expected to be unambiguously positive. The parameter β_1 captures the effect of ask-side transaction (buy pressures) on bid-deal returns (buy quote prices) and the expected sign is positive.

We will call the estimated parameters α_1 and β_2 to represent knocking-off effects, and α_2 and β_1 to represent catch-up effects. (Recall figure 6.1.) Comparing equations (2) and (3), the parameter relationship $\alpha_1 \geq \beta_1$ should hold since it is rather inconceivable that the ask price rises faster than the bid price when the ask-side quotes are transacted by buying pressures. Similarly, $\beta_2 \geq \alpha_2$ is expected since it is more likely that the decline in bid quotes is faster than the ask quotes when the bid quotes are been hit by

selling pressure. If both relationships are held constant, $\alpha_1 = \beta_1$ and/or $\alpha_2 = \beta_2$, then the bid-ask spread is interpreted to remain constant:

$$(5) \quad \Delta s(bestoffer)_t = \alpha_0 + \alpha_1 nd_{t-1}^{plus} + \alpha_2 nd_{t-1}^{minus} + \sum_j \delta \Delta s_{t-j} + \varepsilon_t$$

$$(6) \quad \Delta s(bestbid)_t = \beta_0 + \beta_1 nd_{t-1}^{plus} + \beta_2 nd_{t-1}^{minus} + \sum_j \delta \Delta s_{t-j} + \varepsilon_t$$

$$(7) \quad \Delta s(quotemidpoint)_t = \gamma_0 + \gamma_1 nd_{t-1}^{plus} + \gamma_2 nd_{t-1}^{minus} + \sum_j \delta \Delta s_{t-j} + \varepsilon_t$$

We apply the same regression methodology to estimate the price impact of quote-price returns. Interpretations are similar to the previous equations. Equations (5)–(7) show the best offer returns, best bid returns, and the midpoint of quote prices, respectively.

Again, the parameter relationship $\alpha_1 \geq \beta_1$ should hold if the bid prices lagged behind the ask prices in the process of buying pressure moving the prices up. Similarly, $\beta_2 \geq \alpha_2$ is expected if the best ask price lags behind the bid price in declines when selling pressures drives down the prices. If the bid and ask prices move together, the spread remains constant if a relationship $\alpha_1 = \beta_1$ and/or $\alpha_2 = \beta_2$ is found.

For the explanatory variables of *nd*, we attempt two versions: one with the difference in numbers (*netdeal*) and another with the ratio (*ndr*). Other explanatory variables included in the regression are 1–10 lags of dependent variable. We also control for the time of the day (hour) effect for the regressions.[10]

6.3.1   Results

The regression results are summarized in tables 6.1–6.4 (USD/JPY, deal returns), tables 6.5–6.8 (USD/JPY, quote returns), and tables 6.9–6.12 (EUR/USD, deal returns), and tables 6.13–6.15 (EUR/USD, quote returns).

Overall, the *t*-statistics of variables become insignificant as the chosen frequency becomes lower, regardless of currency pairs and the choice of return definition. For example, the estimated coefficients of explanatory variables (*nd*) are positive and statistically significant in most cases at the 1-minute window, but they become insignificant at the 30-minute window.

The regression results of USD/JPY deal price returns are shown in tables 6.1–6.15. In each table, left-side panels report the results estimated with *netdeal,* and the right-side panels report the results with *ndr*. Tables 6.1 and 6.2 show that price impacts are highly significant at 1- and 5-minute frequencies. The results for 1- and 5-minute periodicity are quite clean and robust. The result is robust with respect to the choice of the ask-deal price,

10. It is well known that foreign exchange markets have intra-day seasonality, see Ito and Hashimoto (2004, 2006) and Ito, Lyons, and Melvin (1998) for such a phenomenon for the yen market, and more generally, Andersen and Bollerslev (1997, 1998) and Baillie and Bollerslev (1990).

Table 6.1   Prediction: USD/JPY 1-minute deal return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1998	9.34E-04	7.23E-05***	1.09E-03	7.74E-05***	63391	1.25E-02	9.80E-04***	1.21E-02	1.06E-03***	63391
1999	7.66E-04	5.83E-05***	4.95E-04	6.36E-05***	60186	8.69E-03	7.83E-04***	8.40E-03	8.43E-04***	60186
2000	5.90E-04	6.56E-05***	7.81E-04	6.82E-05***	37212	7.88E-03	8.13E-04***	8.32E-03	8.52E-04***	37212
2001	6.17E-04	5.58E-05***	6.69E-04	5.93E-05***	44285	7.73E-03	6.89E-04***	8.38E-03	7.25E-04***	44285
2002	5.89E-04	4.93E-05***	4.85E-04	5.15E-05***	49712	7.69E-03	6.31E-04***	6.29E-03	6.55E-04***	49712
2003	5.51E-04	5.23E-05***	4.76E-04	5.43E-05***	42400	5.56E-03	6.55E-04***	7.49E-03	6.83E-04***	42400
Ask deal return										
1998	1.48E-03	5.97E-05***	9.91E-04	6.23E-05***	90950	8.20E-03	4.84E-04***	1.60E-02	7.16E-04***	108425
1999	1.20E-03	4.89E-05***	5.23E-04	5.18E-05***	88435	5.87E-03	4.07E-04***	1.34E-02	6.05E-04***	99849
2000	1.06E-03	5.09E-05***	7.20E-04	5.13E-05***	62049	4.73E-03	3.74E-04***	1.15E-02	5.75E-04***	69572
2001	9.42E-04	4.53E-05***	6.11E-04	4.68E-05***	70365	5.10E-03	3.34E-04***	1.15E-02	5.08E-04***	79179
2002	9.24E-04	4.02E-05***	5.14E-04	4.12E-05***	76168	5.11E-03	3.09E-04***	1.05E-02	4.59E-04***	85919
2003	9.38E-04	4.27E-05***	4.91E-04	4.32E-05***	64972	3.72E-03	3.28E-04***	1.06E-02	4.86E-04***	71439
Bid deal return										
1998	7.75E-04	5.17E-05***	1.59E-03	5.72E-05***	108425	1.81E-02	7.65E-04***	7.54E-03	6.18E-04***	90950
1999	7.56E-04	4.44E-05***	1.08E-03	4.95E-05***	99849	1.29E-02	6.16E-04***	5.85E-03	4.83E-04***	88435
2000	5.40E-04	4.72E-05***	1.23E-03	5.06E-05***	69572	1.20E-02	5.86E-04***	4.91E-03	4.24E-04***	62049
2001	6.03E-04	4.13E-05***	1.08E-03	4.49E-05***	79179	1.11E-02	5.24E-04***	4.53E-03	3.87E-04***	70365
2002	5.51E-04	3.65E-05***	9.64E-04	3.91E-05***	85919	1.08E-02	4.82E-04***	4.28E-03	3.58E-04***	76168
2003	5.16E-04	3.96E-05***	8.93E-04	4.20E-05***	71439	9.12E-03	4.98E-04***	4.80E-03	3.75E-04***	64972

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.2 Prediction: USD/JPY 5-minute deal return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1998	2.53E-04	6.15E-05****	3.08E-04	7.23E-05****	52922	1.18E-02	2.08E-03***	1.35E-02	2.35E-03***	52922
1999	2.11E-04	5.19E-05****	2.79E-04	6.10E-05****	52425	7.72E-03	1.68E-03***	9.97E-03	1.88E-03***	52425
2000	2.50E-04	4.96E-05****	3.67E-04	5.41E-05****	47782	8.96E-03	1.37E-03***	1.02E-02	1.48E-03***	47782
2001	1.53E-04	4.59E-05****	2.50E-04	5.22E-05****	48571	5.07E-03	1.32E-03***	7.01E-03	1.47E-03***	48571
2002	2.16E-04	4.26E-05****	2.49E-04	4.73E-05****	49883	7.06E-03	1.27E-03***	7.13E-03	1.38E-03***	49883
2003	3.93E-04	4.29E-05****	1.73E-04	4.70E-05****	42979	8.56E-03	1.24E-03***	6.47E-03	1.35E-03***	42979
Ask deal return										
1998	2.82E-04	5.85E-05****	4.75E-04	6.87E-05****	59034	1.67E-02	1.93E-03***	1.13E-02	1.88E-03***	57305
1999	2.42E-04	4.94E-05****	4.17E-04	5.80E-05****	58570	7.39E-03	1.31E-03***	1.27E-02	1.67E-03***	58570
2000	2.43E-04	4.71E-05****	5.02E-04	5.13E-05****	54148	6.50E-03	1.105E-03***	1.27E-02	1.32E-03***	54148
2001	1.86E-04	4.34E-05****	4.03E-04	4.93E-05****	55211	4.64E-03	1.00E-03***	1.02E-02	1.30E-03***	55211
2002	2.32E-04	4.03E-05****	3.58E-04	4.47E-05****	56313	6.53E-03	9.58E-04***	9.18E-03	1.22E-03***	56313
2003	4.01E-04	4.07E-05****	2.74E-04	4.45E-05****	48562	6.42E-03	9.53E-04***	8.40E-03	1.20E-03***	48562
Bid deal return										
1998	4.25E-04	5.93E-05****	3.78E-04	7.01E-05****	57305	1.04E-02	1.64E-03***	1.68E-02	2.11E-03***	59034
1999	3.58E-04	5.01E-05****	3.40E-04	5.91E-05****	56617	1.20E-02	1.56E-03***	8.50E-03	1.52E-03***	56617
2000	4.04E-04	4.73E-05****	4.14E-04	5.20E-05****	52806	1.22E-02	1.25E-03***	7.39E-03	1.15E-03***	52806
2001	2.93E-04	4.42E-05****	2.99E-04	5.04E-05****	53251	8.30E-03	1.22E-03***	6.57E-03	1.14E-03***	53251
2002	3.20E-04	4.09E-05****	2.84E-04	4.57E-05****	54555	9.52E-03	1.16E-03***	6.77E-03	1.08E-03***	54555
2003	4.77E-04	4.15E-05****	1.95E-04	4.56E-05****	46880	1.10E-02	1.15E-03***	5.05E-03	1.07E-03***	46880

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

bid-deal price, or midpoint. The net buy (sell) pressure represented by the order flows has predictive power on the price movements in the following one to five minutes. The result is confirmed in each year in the sample. Tables 6.3 and 6.4 show that these impacts become statistically insignificant in the 15-minute and 30-minute windows.

As for the parameter relationships, we only find significant parameter relationships of $\alpha_1 \geq \beta_1$ and $\beta_2 \geq \alpha_2$ in the 1-minute deal return regression using *netdeal.* In this case, the catch up effects lag behind the knock-off effects. In other cases, it is more common that the bid-ask spread becomes temporarily more narrow in the course of transaction at a very high-frequency (1 minute at the longest) interval.

We can make a rough calculation about the magnitude of predictable movement, provided that data on order flows are available. For example, an increase in ask-deal price when one unit of order flow to buy (nd^{plus}) is observed in the left-panel, the yen/dollar rate, in terms of ask-side deal prices, is supposed to move 0.00148 (the coefficient) in 1998 and around 0.0009 in 2001–2003. The appendix shows that the maximum order flow counts are in the order of 20 to 25. So that the impact of very large order flows on the deal price change is in the order of 0.02 to 0.03. The unit of the left-side variable is the percentage change of the yen/dollar rate, so that 0.02 to 0.03 translates into 0.02 yen or 0.03 yen, when the yen/dollar rate is 100 (and one-percent change means 0.01 yen). This exceeds the average bid-ask spread during the active trading hours.[11]

Similarly, the right-side panel indicates that the ask-side deal prices would respond by 0.018 in 1998, and by a slightly smaller margin by 2003, to a one-sided (100 percent) order-flow direction. The magnitude of 0.018 translates into a change by 0.018 yen/dollar when the yen/dollar level is 100. Similarly, the magnitude exceeds the busiest-hour bid-ask spread.

Tables 6.5–6.8 reports the price impact of USD/JPY quote returns. Results are quite similar to deal-price returns. Price impact is significant at 1-minute and 5-minute frequencies. Predictability of changes in bid and ask quotes in response to order flows, that is, buy or sell pressure, of the preceding time window is clearly established for the 1-minute and 5-minute windows. The number of significant coefficients decreases in the 15-minute window and represents almost no significance in the 30-minute frequency. The transaction at $t-1$ significantly moves quote prices from $t-1$ to t up to the 5-minute window, but the price impact disappears at 30-minute frequency.

The parameter relationships of $\alpha_1 \geq \beta_1$ or $\beta_2 \geq \alpha_2$ do not necessarily hold in many cases for 1-minute quote returns and 5-minute quote returns. So, we cannot generalize whether the knocking-off effects are larger than the

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11. For descriptions of bid-ask spreads depending on GMT hours (intra-day seasonality), see Ito and Hashimoto (2004).

Table 6.3   **Prediction: USD/JPY 15-minute deal return**

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1998	3.16E-05	8.61E-05	8.07E-05	1.14E-04	23149	5.84E-03	6.53E-03	6.74E-03	7.35E-03	23149
1999	-1.81E-04	7.13E-05***	-1.47E-04	9.58E-05*	22821	2.42E-03	5.09E-03	3.76E-03	5.92E-03	22821
2000	6.53E-05	6.79E-05	-1.93E-05	7.93E-05	22292	5.76E-03	3.97E-03*	2.41E-03	4.15E-03	22292
2001	1.15E-04	6.32E-05**	3.49E-05	7.94E-05	22354	4.77E-03	3.73E-03	4.79E-03	4.25E-03	22354
2002	-3.46E-05	5.79E-05	1.73E-04	7.00E-05***	22569	5.97E-03	3.55E-03**	3.58E-03	4.05E-03	22569
2003	2.79E-05	5.92E-05	-7.10E-06	6.98E-05	19113	7.87E-03	3.60E-03**	-4.45E-03	4.04E-03	19113
Ask deal return										
1998	4.25E-05	8.52E-05	1.14E-04	1.12E-04	23654	5.17E-03	5.98E-03	8.87E-03	7.11E-03	23654
1999	-1.84E-04	7.07E-05***	-1.08E-04	9.49E-05	23272	4.33E-03	4.73E-03	5.56E-03	5.79E-03	23272
2000	9.12E-05	6.70E-05*	1.81E-05	7.82E-05	23057	8.10E-03	3.55E-03**	2.57E-03	4.01E-03	23057
2001	1.15E-04	6.22E-05**	8.00E-05	7.83E-05	23260	4.76E-03	3.30E-03*	7.02E-03	4.07E-03**	23260
2002	-1.96E-05	5.71E-05	2.26E-04	6.91E-05***	23445	5.57E-03	3.11E-03**	5.80E-03	3.90E-03*	23445
2003	5.39E-05	5.86E-05	1.24E-05	6.93E-05	19680	8.30E-03	3.25E-03***	1.29E-03	3.90E-03	19680
Bid deal return										
1998	9.71E-05	8.66E-05	1.26E-03	1.15E-04	23370	1.02E-02	6.52E-03	9.71E-03	7.17E-03	23370
1999	-1.23E-04	7.09E-05*	-1.12E-04	9.55E-05	23266	7.01E-03	5.00E-03*	1.90E-03	5.33E-03	23266
2000	1.14E-04	6.71E-05**	2.91E-07	7.87E-05	23009	8.82E-03	3.84E-03**	2.28E-03	3.66E-03	23009
2001	1.52E-04	6.27E-05****	6.69E-05	7.89E-05	22926	9.46E-03	3.63E-03***	4.41E-03	3.83E-03	22926
2002	4.93E-06	5.74E-05	1.81E-04	6.97E-05***	23058	8.61E-03	3.47E-03***	2.01E-03	3.67E-03	23058
2003	5.84E-05	5.90E-05	2.62E-05	6.97E-05	19421	1.03E-02	3.54E-03***	-1.35E-03	3.78E-03	19421

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.4   Prediction: USD/JPY 30-minute deal return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
					Log middle price					
1998	-1.88E-04	1.10E-04*	-5.97E-05	1.66E-04	11805	-2.31E-02	1.58E-02	7.52E-04	1.87E-02	11805
1999	-1.86E-04	9.21E-05***	-2.87E-05	1.38E-04	11720	-6.08E-03	1.26E-02	6.20E-03	1.53E-02	11720
2000	2.28E-04	8.94E-05***	-2.65E-05	1.12E-04	11824	3.39E-03	9.50E-03	9.21E-03	1.02E-02	11824
2001	1.09E-04	8.28E-05	-5.41E-05	1.14E-04	11777	4.02E-03	8.75E-03	-8.36E-04	1.03E-02	11777
2002	-3.43E-05	7.68E-05	1.34E-04	9.98E-05	11823	-3.12E-04	8.45E-03	7.33E-03	9.93E-03	11823
2003	-7.96E-05	7.97E-05	5.56E-06	9.98E-05	9890	-4.03E-03	8.99E-03	-6.58E-03	1.03E-02	9890
					Ask deal return					
1998	-2.07E-04	1.10E-04*	-6.34E-05	1.65E-04	11870	-1.92E-02	1.52E-02	-2.23E-03	1.85E-02	11870
1999	-1.70E-04	9.19E-05*	-1.69E-05	1.38E-04	11828	-5.13E-03	1.21E-02	7.00E-03	1.51E-02	11828
2000	2.17E-04	8.88E-05***	6.35E-07	1.11E-04	11946	1.40E-03	8.87E-03	1.13E-02	1.01E-02	11946
2001	1.08E-04	8.27E-05	-3.50E-05	1.14E-04	11894	3.95E-03	8.28E-03	-6.01E-04	1.02E-02	11894
2002	-3.39E-05	7.67E-05	1.63E-04	9.96E-05	11955	-2.26E-03	7.95E-03	1.03E-02	9.75E-03	11955
2003	-5.62E-05	7.95E-05	1.70E-05	9.97E-05	9980	-1.36E-03	8.43E-03	-6.56E-03	1.02E-02	9980
					Bid deal return					
1998	-1.48E-04	1.11E-04	-1.88E-05	1.67E-04	11839	-2.15E-02	1.59E-02	1.76E-02	1.82E-02	11839
1999	-1.73E-04	9.21E-05*	-1.02E-05	1.38E-04	11763	-2.04E-03	1.25E-02	4.11E-03	1.48E-02	11763
2000	2.67E-04	8.96E-05***	-2.63E-05	1.12E-04	11904	5.20E-03	9.43E-03	1.05E-02	9.70E-03	11904
2001	1.36E-04	8.27E-05	-2.95E-05	1.14E-04	11852	7.94E-03	8.69E-03	-1.80E-03	9.92E-03	11852
2002	-9.49E-06	7.67E-05	1.39E-04	9.97E-05	11905	4.70E-03	8.36E-03	4.99E-03	9.50E-03	11905
2003	-7.84E-05	7.98E-05	1.32E-05	1.00E-04	9925	-3.76E-03	8.96E-03	-5.26E-03	1.01E-02	9925

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.5 **Prediction: USD/JPY 1-minute quote return**

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1998	7.03E-04	3.20E-05***	8.80E-04	3.45E-05***	262271	0.0045455	2.29E-04***	3.83E-03	2.42E-04***	251500
1999	3.98E-04	2.76E-05***	3.86E-04	2.99E-05***	233065	2.76E-03	1.93E-04***	2.31E-03	2.03E-04***	225065
2000	3.22E-04	2.71E-05***	4.16E-04	2.82E-05***	191789	2.25E-03	1.67E-04***	1.81E-03	1.73E-04***	184434
2001	3.70E-04	2.47E-05***	3.93E-04	2.62E-05***	208058	2.37E-03	1.55E-04***	2.05E-03	1.62E-04***	200423
2002	3.04E-04	2.22E-05***	3.18E-04	2.34E-05***	214595	1.96E-03	1.44E-04***	1.63E-03	1.50E-04***	206908
2003	3.20E-04	2.44E-05***	3.11E-04	2.55E-05***	170934	1.60E-03	1.56E-04***	1.78E-03	1.63E-04***	165535
Ask deal return										
1998	1.13E-03	3.34E-05***	1.10E-03	3.63E-05***	262271	0.0057625	2.41E-04***	5.29E-03	2.55E-04***	251500
1999	6.95E-04	2.84E-05***	5.17E-04	3.11E-05***	233065	3.50E-03	2.01E-04***	3.29E-03	2.11E-04***	225065
2000	5.82E-04	2.80E-05***	5.59E-04	2.93E-05***	191789	2.93E-03	1.74E-04***	2.59E-03	1.80E-04***	184434
2001	6.31E-04	2.56E-05***	5.41E-04	2.74E-05***	208058	3.03E-03	1.62E-04***	2.91E-03	1.69E-04***	200423
2002	5.30E-04	2.30E-05***	4.67E-04	2.43E-04***	214595	2.61E-03	1.50E-04***	2.39E-03	1.56E-04***	206908
2003	4.32E-04	2.54E-05***	5.06E-04	2.64E-05***	170934	2.16E-03	1.62E-04***	2.32E-03	1.69E-04***	165535
Bid deal return										
1998	1.08E-03	3.54E-05***	1.51E-03	3.79E-05***	262271	0.0069327	2.54E-04***	5.46E-03	2.69E-04***	251500
1999	5.20E-04	2.87E-05***	6.93E-04	3.09E-05***	233065	0.0036533	2.01E-04***	2.82E-03	2.12E-04***	225065
2000	4.91E-04	2.85E-05***	7.18E-04	2.94E-05***	191789	0.0030469	1.75E-04***	2.43E-03	1.82E-04***	184434
2001	5.37E-04	2.60E-05***	7.01E-04	2.74E-05***	208058	3.27E-03	1.64E-04***	2.67E-03	1.71E-04***	200423
2002	4.52E-04	2.33E-05***	5.65E-04	2.43E-05***	214595	2.72E-03	1.51E-04***	2.19E-03	1.58E-04***	206908
2003	5.33E-04	2.52E-05***	4.53E-04	2.66E-05***	170934	0.0022423	1.63E-04***	2.46E-03	1.69E-04***	165535

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.6   **Prediction: USD/JPY 5-minute quote return**

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1998	2.57E-04	5.24E-05***	3.07E-04	6.21E-05***	71787	6.57E-03	1.23E-03***	5.60E-03	1.33E-03***	71359
1999	5.20E-05	4.36E-05	1.04E-04	5.16E-05**	70948	2.99E-03	9.65E-04***	1.99E-03	1.04E-03*	70507
2000	7.97E-05	4.03E-05*	1.78E-04	4.42E-05***	69997	2.38E-03	7.26E-04***	3.46E-03	7.54E-04***	69374
2001	7.16E-05	3.73E-05*	1.41E-04	4.27E-05***	70438	2.23E-03	6.90E-04***	2.74E-03	7.43E-04***	69818
2002	1.06E-04	3.49E-05***	1.29E-04	3.89E-05***	70840	3.42E-03	6.67E-04***	1.95E-03	7.12E-04***	70322
2003	2.67E-04	3.61E-05***	8.46E-05	3.99E-05**	58768	3.56E-03	7.00E-04***	1.73E-03	7.48E-04**	58421
Ask deal return										
1998	6.65E-04	5.51E-05***	7.92E-04	6.54E-05***	71787	0.012117	1.31E-03***	9.71E-03	1.42E-03***	71359
1999	1.08E-04	4.40E-05**	1.85E-04	5.20E-05***	70948	3.60E-03	9.75E-04***	2.45E-03	1.06E-03**	70507
2000	1.62E-04	4.08E-05***	2.73E-04	4.46E-05***	69997	2.95E-03	7.37E-04***	3.99E-03	7.66E-04***	69374
2001	1.59E-04	3.79E-04***	2.31E-04	4.33E-05***	70438	3.02E-03	7.03E-04***	3.27E-03	7.57E-03	69818
2002	1.88E-04	3.53E-05***	2.10E-04	3.94E-05***	70840	4.22E.03	6.77E-04***	2.61E-03	7.24E-04***	70322
2003	3.17E-04	3.65E-05***	1.42E-04	4.03E-05***	58768	3.99E-03	7.10E-04***	1.98E-03	7.59E-04	58421
Bid deal return										
1998	2.75E-04	5.25E-05***	3.11E-04	6.22E-05***	71787	6.75E-03	1.23E-03***	6.21E-03	1.33E-03***	71359
1999	1.57E-04	4.42E-05***	2.04E-04	5.23E-05***	70948	4.22E-03	9.80E-04***	3.12E-03	1.06E-03***	70507
2000	1.53E-04	4.07E-05***	2.50E-04	4.47E-05***	69997	3.20E-03	7.35E-04***	4.29E-03	7.65E-04***	69374
2001	1.64E-04	3.78E-05***	2.57E-04	4.33E-05***	70438	3.17E-03	7.02E-04***	3.79E-03	7.56E-04***	69818
2002	1.57E-04	3.51E-05***	1.96E-04	3.93E-05***	70840	3.93E-03	6.74E-04***	2.50E-03	7.20E-04***	70322
2003	3.26E-04	3.65E-05***	1.41E-04	4.05E-05***	58768	4.24E-03	7.10E-04***	2.54E-03	7.58E-04***	58421

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.7   Prediction: USD/JPY 15-minute quote return

	netdeal					ndr				
	ndplus	s.e.	*ndminus*	s.e.	NOB	*ndplus*	s.e.	*ndminus*	s.e.	NOB
Log middle price										
1998	1.05E-04	8.48E-05	1.32E-04	1.12E-04	24118	5.62E-03	5.78E-03	8.13E-03	6.68E-03	24108
1999	-1.96E-04	6.91E-05***	-2.17E-04	9.29E-05**	24141	1.89E-03	4.37E-03	-2.10E-03	4.91E-03	24124
2000	1.57E-05	6.42E-05	-8.59E-05	7.52E-05	24337	2.43E-03	3.18E-03	-1.22E-03	3.30E-03	24314
2001	5.95E-05	5.98E-05	-2.35E-05	7.56E-05	24386	1.38E-03	2.97E-03	2.13E-04	3.39E-03	24355
2002	-7.39E-05	5.51E-05	1.58E-04	6.68E-05**	24477	3.56E-03	2.79E-03	-9.54E-04	3.25E-03	24454
2003	-1.32E-05	5.72E-05	-1.44E-05	6.76E-05	20306	4.10E-03	3.02E-03	-2.39E-03	2.44E-03	20293
Ask deal return										
1998	3.93E-04	8.72E-05***	4.21E-04	1.16E-04***	24118	1.69E-02	5.99E-03***	1.53E-02	6.95E-03**	24108
1999	-1.66E-04	6.93E-05**	-1.97E-04	9.31E-05**	24141	2.55E-03	4.39E-03	-1.75E-03	4.93E-03	24124
2000	4.52E-05	6.44E-05	-6.02E-05	7.54E-05	24337	2.18E-03	3.19E-03	-1.34E-04	3.32E-03	24314
2001	9.45E-05	6.01E-05	5.84E-07	7.59E-05	24386	1.91E-03	2.99E-03	6.04E-04	3.41E-03	24355
2002	-2.80E-05	5.54E-05	1.95E-04	6.71E-05***	24477	4.62E-03	2.81E-03	6.99E-04	3.27E-03	24454
2003	1.04E-05	5.74E-05	-4.06E-07	6.78E-05	20306	3.81E-03	3.03E-03	-1.26E-03	3.46E-03	20293
Bid deal return										
1998	4.38E-05	8.49E-05	1.22E-04	1.12E-04	24118	4.09E-03	5.78E-03	8.99E-03	6.67E-03	24108
1999	-1.80E-04	6.94E-05***	-1.81E-04	9.34E-05*	24141	2.86E-03	4.40E-03	-1.17E-03	4.94E-03	24124
2000	4.10E-05	6.46E-05	-4.99E-05	7.56E-05	24337	4.15E-03	3.20E-03	-1.05E-03	3.32E-03	24314
2001	8.25E-05	6.01E-05	2.03E-05	7.61E-05	24386	2.50E-03	3.00E-03	1.29E-03	3.41E-03	24355
2002	-7.44E-05	5.53E-05	1.71E-04	6.70E-05**	24477	3.78E-03	2.80E-03	-1.37E-03	3.26E-03	24454
2003	4.79E-06	5.76E-05	1.10E-05	6.81E-05	20306	0.0056029	3.05E-03*	-2.38E-03	3.47E-03	20293

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.8   Prediction: USD/JPY 30-minute quote return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
					Log middle price					
1998	-1.27E-04	1.10E-04	-9.05E-06	1.67E-04	11919	-1.43E-02	1.52E-02	9.74E-03	1.80E-02	11918
1999	-2.06E-04	9.07E-05**	-7.29E-05	1.36E-04	11952	-7.84E-03	1.13E-02	-3.08E-03	1.38E-02	11946
2000	2.03E-04	8.77E-05**	-7.16E-05	1.10E-04	12066	-7.72E-04	8.55E-03	5.78E-03	9.22E-03	12064
2001	8.23E-05	8.14E-05	-4.34E-05	1.12E-04	12075	2.72E-03	7.93E-03	-6.13E-03	9.34E-03	12066
2002	-6.70E-05	7.54E-05	1.18E-04	9.78E-05	12103	-2.37E-03	7.56E-03	7.05E-04	9.00E-03	12097
2003	-9.75E-05	7.88E-05	-4.16E-05	9.88E-05	10033	-5.81E-03	8.29E-03	-1.27E-02	9.69E-03	10032
					Ask deal return					
1998	3.62E-05	1.13E-04	1.93E-04	1.71E-04	11919	-9.26E-04	1.57E-02	2.11E-02	1.86E-02	11918
1999	-1.92E-04	9.08E-05**	-7.11E-05	1.36E-04	11952	-7.92E-03	1.14E-02	3.66E-04	1.38E-02	11946
2000	2.36E-04	8.78E-05***	-6.09E-05	1.10E-04	12066	6.00E-05	8.57E-03	6.84E-03	9.25E-03	12064
2001	8.56E-05	8.16E-05	-6.78E-05	1.13E-04	12075	9.45E-04	7.94E-03	-6.21E-03	9.36E-03	12066
2002	-5.43E-05	7.56E-05	1.39E-04	9.80E-05	12103	-3.15E-03	7.58E-03	2.53E-03	9.02E-03	12097
2003	-8.16E-05	7.89E-05	-4.23E-05	9.89E-05	10033	-6.17E-03	8.30E-03	-1.09E-02	9.70E-03	10032
					Bid deal return					
1998	-1.52E-04	1.11E-04	5.03E-06	1.67E-04	11919	-1.32E-02	1.53E-02	9.54E-03	1.81E-02	11918
1999	-2.00E-04	9.09E-05**	-4.88E-05	1.37E-04	11952	-6.04E-03	1.14E-02	-5.22E-03	1.38E-02	11946
2000	1.93E-04	8.81E-05**	-5.72E-05	1.10E-04	12066	-2.00E-04	8.59E-03	5.86E-03	9.26E-03	12064
2001	1.06E-04	8.18E-05	1.28E-05	1.13E-04	12075	6.32E-03	7.98E-03	-4.59E-03	9.39E-03	12066
2002	-5.60E-05	7.57E-05	1.22E-04	9.82E-05	12103	-1.02E-04	7.59E-03	2.04E-04	9.04E-03	12097
2003	-8.85E-05	7.92E-05	-1.96E-05	9.95E-05	10033	-3.91E-03	8.34E-03	-1.31E-02	9.76E-03	10032

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

catch-up effects. The magnitude of coefficients is not as large as in the case of deal returns.

As for the magnitude of the euro price impacts, rough calculations show that the price impacts (coefficient, like 0.000335 under 1999 in table 6.5 ask-side deals, multiplied by 20 *netdeals* in one minute) when very large order flows occur during busy hours (low bid-ask spread) exceed the size of the lowest bid-ask spread (0.01 EUR/USD). Similarly, the when the net-deal ratio is 1, then the impact was estimated to exceed the bid-ask spread.

Regression results of EUR/USD deal price returns are summarized in tables 6.9–6.12. As clearly seen in these tables, price impact is significant at the 1-minute frequency. Looking at the price impact at 5-minute frequency, some of the price impacts in 1999 and 2000 are not significantly estimated. For example, estimated parameter nd^{minus} for midpoint return and bid-side deal return in 1999 and 2000, parameter nd^{plus} for midpoint return in 1999, and parameters nd^{plus} and nd^{minus} for ask-side deal return in 1999 (all estimated with *netdeal*) are not significant at 10 percent. However, since 2001 deal price returns, both in ask and bid, have been significant at 1 percent in the 5 minute window (table 6.14), just like in the case of USD/JPY (table 6.6). At 15-minute and 30-minute frequencies, most of the coefficients are not statistically significant.

Impacts of order flows on bid and ask prices did not show definite signs of relative magnitude, hence no conclusive statement is possible as for the impacts on the bid-ask spread.

Tables 6.13–6.16 reports the price impact of EUR/USD quote returns. Again, significant price impacts at the 1-minute frequency are found, but some of the parameters in early years are not significant at 5-minute frequency.[12] However, significance disappears at the 15-minute and 30-minute frequencies.

The relative magnitudes of α_1 and β_1 in case of nd^{plus} and of β_2 and α_2 of nd^{minus} show some definite relationships to indicate that the knocking-off effects are faster than the catch-up effects in 1-minute and 5-minute returns.

In sum, our tests turned out to be successful in finding some predictive power of exchange rate changes based on order flows for both USD/JPY and EUR/USD, at least up to 5 minutes. The results are consistent with a wide-spread notion among dealers and market participants that private information on order flows in real time—that is, aggregated every minute—does help predicting the exchange rate movements in the following several minutes. However, the predictability (and information) is short-lived. We fail to detect any predictability even at the 30-minute frequency. In that

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12. Parameter nd^{plus} for midpoint return in 1999, 2000 (*netdeal*), 1999 (*ndr*), bid-side deal return in 1999 (*netdeal, ndr*), ask-side deal return in 1999 (*netdeal*), and parameter nd^{plus} for mid point return from 1999–2001, bid-side deal return in 1999 and 2000 (*netdeal and ndr*) and ask-side deal return 1999 to 2000 (*netdeal and ndr*) are not significant at 10%.

Table 6.9 **Prediction: EUR/USD 1-minute deal return**

	netdeal					ndr				
	ndplus	s.e.	ndhminus	s.e.	NOB	ndplus	s.e.	ndhminus	s.e.	NOB
					Log middle price					
1999	3.12E-04	2.88E-05***	3.09E-04	3.01E-05***	94682	5.20E-03	4.50E-04***	5.54E-03	4.73E-04***	94682
2000	4.12E-04	3.43E-05***	3.94E-04	3.56E-05***	115301	6.60E-03	5.59E-04***	7.29E-03	5.84E-04***	115301
2001	2.95E-04	3.33E-05***	3.85E-04	3.41E-05***	106335	5.32E-03	5.20E-04***	6.43E-03	5.44E-04***	106335
2002	2.22E-04	2.93E-05***	2.38E-04	3.05E-05***	90761	4.07E-03	4.53E-04***	4.59E-03	4.78E-04***	90761
2003	3.09E-04	2.79E-05***	2.48E-04	2.87E-05***	107231	4.46E-03	4.55E-04***	4.98E-03	4.74E-04***	107231
					Ask deal return					
1999	3.35E-04	2.52E-05***	5.59E-04	2.65E-05***	124575	4.22E-03	2.91E-04***	8.09E-03	3.89E-04***	124575
2000	3.99E-04	3.07E-05***	6.59E-04	3.21E-05***	143585	4.69E-03	3.79E-04***	1.05E-02	4.92E-04***	143585
2001	2.86E-04	2.97E-05***	6.31E-04	3.06E-05***	134865	3.84E-03	3.43E-04***	9.07E-03	4.56E-04***	134865
2002	2.28E-04	2.52E-05***	4.26E-04	2.65E-05***	121033	2.72E-03	2.79E-04***	6.70E-03	3.82E-04***	121033
2003	3.02E-04	2.51E-05***	4.15E-04	2.61E-05***	132283	3.53E-03	3.02E-04***	6.80E-03	4.01E-04***	132283
					Bid deal return					
1999	5.33E-04	2.61E-05***	3.23E-04	2.69E-05***	118122	7.77E-03	3.86E-04***	4.34E-03	3.24E-04***	118122
2000	6.68E-04	3.15E-05***	4.20E-04	3.24E-05***	138445	9.97E-03	4.87E-04***	5.45E-03	4.12E-04***	138445
2001	4.99E-04	3.05E-05***	3.88E-04	3.10E-05***	128689	8.20E-03	4.49E-04***	4.29E-03	3.78E-04***	128689
2002	3.99E-04	2.63E-05***	2.46E-04	2.70E-05***	114936	6.38E-03	3.82E-04***	3.16E-03	3.09E-04***	114936
2003	4.74E-04	2.56E-05***	2.46E-04	2.63E-05***	128043	6.53E-03	3.94E-04***	3.72E-03	3.28E-04***	128043

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.10   Prediction: EUR/USD 5-minute deal return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1999	5.71E-05	3.63E-05	−4.29E-05	3.95E-05	49697	4.07E-03	1.41E-03**	2.77E-03	1.52E-03*	49697
2000	1.40E-04	4.67E-05**	6.12E-05	5.07E-05	51451	8.26E-03	1.96E-03***	4.22E-03	2.13E-03**	51451
2001	1.43E-04	4.39E.05**	1.53E-04	4.69E-05***	51035	1.01E-02	1.66E-03***	4.25E-03	1.84E-03**	51035
2002	1.22E-04	3.46E-05***	1.45E-04	3.80E-05***	51551	6.11E-03	1.28E-03***	4.52E-03	1.38E-03***	51551
2003	1.21E-04	3.80E-05**	1.43E-04	4.12E-05***	48206	5.78E-03	1.48E-03***	7.86E-03	1.63E-03***	48206
Ask deal return										
1999	5.58E-05	3.47E-05	5.14E-05	3.76E-05	54902	4.27E-03	1.05E-03***	4.35E-03	1.35E-03***	54902
2000	1.49E-04	4.46E-05**	1.59E-04	4.84E-05***	56457	6.00E-03	1.44E-03***	7.47E-03	1.88E-03***	56457
2001	1.53E-04	4.19E-05***	2.19E-04	4.47E-05***	56446	7.68E-03	1.22E-03***	6.59E-03	1.62E-03***	56446
2002	1.32E-04	3.31E-05***	1.98E-04	3.63E-05***	56928	3.77E-03	9.48E-04***	5.98E-03	1.22E-03***	56928
2003	1.28E-04	3.63E-05***	1.87E-04	3.94E-05***	52520	4.72E-03	1.12E-03***	9.21E-03	1.44E-03***	52520
Bid deal return										
1999	1.42E-04	3.51E-05***	−8.16E-06	3.84E-05	53563	6.77E-03	1.30E-03***	2.67E-03	1.20E-03**	53563
2000	2.03E-04	4.51E-05***	7.58E-05	4.92E-05	55121	1.04E-02	1.79E-03***	3.63E-03	1.65E-03**	55121
2001	2.09E-04	4.24E-05***	1.65E-04	4.54E-05***	55093	1.18E-02	1.52E-03***	3.58E-03	1.40E-03**	55093
2002	1.73E-04	3.34E-05***	1.50E-04	3.68E-05***	55772	7.49E-03	1.16E-03***	3.78E-03	1.05E-03***	55772
2003	1.65E-04	3.70E-05***	1.55E-04	4.02E-05***	51031	7.54E-03	1.38E-03***	6.90E-03	1.33E-03***	51031

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.11   Prediction: EUR/USD 15-minute deal return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1999	−9.27E-05	5.24E-05*	−3.54E-05	6.25E-05	21290	1.42E-03	4.05E-03	6.72E-04	4.53E-03	21290
2000	1.27E-05	6.53E-05	−1.67E-04	7.75E-05**	22128	2.88E-03	5.26E-03	−1.64E-03	5.95E-03	22128
2001	−6.66E-05	6.18E-05	1.77E-04	7.04E-05***	22439	5.52E-03	4.43E-03	2.26E-03	4.99E-03	22439
2002	6.21E-05	4.80E-05	−1.29E-04	5.76E-05**	22724	−1.38E-03	3.57E-03	2.31E-03	3.90E-03	22724
2003	7.73E-05	5.58E-05	−1.99E-05	6.38E-05	19881	2.99E-03	4.63E-03	1.36E-02	5.25E-03**	19881
Ask deal return										
1999	−8.45E-05	5.11E-05*	−1.78E-05	6.07E-05	22545	1.04E-03	3.26E-03	6.75E-04	4.19E-03	22545
2000	1.72E-05	6.39E-05	−1.45E-04	7.59E-05*	23110	2.80E-03	4.45E-03	8.25E-04	5.56E-03	23110
2001	−5.06E-05	6.06E-05	1.89E-04	6.92E-05***	23347	4.35E-03	3.82E-03	3.53E-03	4.71E-03	23347
2002	6.41E-05	4.74E-05	−1.15E-04	5.70E-05**	23388	−1.86E-03	3.18E-03	4.43E-03	3.74E-03	23388
2003	7.58E-05	5.54E-05	−1.78E-05	6.35E-05	20132	2.73E-03	4.40E-03	1.43E-02	5.14E-03***	20132
Bid deal return										
1999	−6.71E-05	5.15E-05	−3.07E-05	6.15E-05	22090	4.30E-03	3.86E-03	1.13E-03	3.80E-03	22090
2000	4.08E-05	6.44E-05	−1.53E-04	7.64E-05**	22874	5.53E-03	5.01E-03	−1.27E-03	5.09E-03	22874
2001	−4.50E-05	6.12E-05	1.86E-04	6.98E-05****	23002	7.40E-03	4.28E-03*	3.12E-03	4.46E-03	23002
2002	8.42E-05	4.75E-05*	−1.18E-04	5.70E-05***	23337	9.49E-04	3.45E-03	2.20E-03	3.44E-03	23337
2003	9.56E-05	5.57E-05*	−8.44E-06	6.38E-05	20054	5.09E-03	4.59E-03	1.26E-02	5.02E-03**	20054

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.12   Prediction: EUR/USD 30-minute deal return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1999	-6.76E-05	6.90E-05	-9.24E-05	8.72E-05	11473	4.24E-03	9.01E-03	-1.23E-02	1.05E-02	11473
2000	-1.80E-04	8.50E-05**	-3.64E-04	1.08E-04***	11840	-1.22E-03	1.19E-02	-2.44E-02	1.37E-02*	11840
2001	-7.01E-05	8.04E-05	1.13E-04	9.66E-05	11865	-4.70E-03	1.05E-02	-5.23E-03	1.22E-02	11865
2002	-9.72E-05	6.31E-05	-3.08E-05	8.19E-05	11914	-1.10E-02	8.59E-03	3.96E-04	9.38E-03	11914
2003	9.64E-06	7.52E-05	-4.65E-05	9.30E-05	10025	-1.84E-02	1.22E-02	1.64E-02	1.42E-02	10025
Ask deal return										
1999	-6.60E-05	6.83E-05	-7.14E-05	8.59E-05	11706	3.69E-03	8.10E-03	-1.04E-02	1.02E-02	11706
2000	-1.80E-04	8.47E-05**	-3.63E-04	1.08E-04***	11948	5.82E-04	1.12E-02	-2.25E-02	1.35E-02*	11948
2001	-6.36E-05	8.02E-05	1.22E-04	9.64E-05	11957	-2.48E-03	9.91E-03	-4.07E-03	1.20E-02	11957
2002	-9.18E-05	6.30E-05	-3.43E-05	8.18E-05	11995	-9.95E-03	8.24E-03	1.14E-03	9.28E-03	11995
2003	1.01E-05	7.52E-05	-3.39E-05	9.29E-05	10044	-1.73E-02	1.19E-02	1.72E-02	1.40E-02	10044
Bid deal return										
1999	-5.19E-05	6.85E-05	-9.24E-05	8.68E-05	11615	5.16E-03	8.90E-03	-7.83E-03	9.67E-03	11615
2000	-1.63E-04	8.50E-05*	-3.48E-04	1.08E-04***	11906	-1.55E-03	1.18E-02	-1.88E-02	1.33E-02	11906
2001	-6.09E-05	8.04E-05	1.14E-04	9.67E-05	11946	-3.28E-03	1.04E-02	-2.11E-03	1.17E-02	11946
2002	-8.87E-05	6.31E-05	-2.73E-05	8.19E-05	11974	-9.24E-03	8.54E-03	1.27E-03	9.03E-03	11974
2003	1.35E-05	7.54E-05	-5.17E-05	9.32E-05	10030	-1.64E-02	1.22E-02	1.58E-02	1.42E-02	10030

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.13   Prediction: EUR/USD 1-minute quote return

	netdeal					ndr				
	ndplus	s.e.	ndhminus	s.e.	NOB	ndplus	s.e.	ndhminus	s.e.	NOB
Log middle price										
1999	1.59E-04	1.97E-05***	1.66E-04	2.05E-05***	195862	1.25E-03	1.73E-04***	1.25E-03	1.80E-04***	191535
2000	2.01E-04	2.47E-05***	2.68E-04	2.57E-05***	208196	1.81E-03	2.33E-04***	1.71E-03	2.43E-04***	204498
2001	1.52E-04	2.46E-05***	2.54E-04	2.53E-05***	188917	1.79E-03	2.20E-04***	1.50E-03	2.30E-04***	185282
2002	1.17E-04	2.20E-05***	1.51E-04	2.31E-05***	156517	1.45E-03	1.98E-04***	1.39E-03	2.07E-04***	153833
2003	1.69E-04	2.09E-05***	1.31E-04	2.16E-05***	180919	1.20E-03	1.96E-04***	1.48E-03	2.03E-04***	178101
Ask deal return										
1999	2.66E-04	2.04E-05***	3.20E-04	2.12E-05***	195862	2.03E-03	1.79E-04***	1.66E-03	1.86E-04***	191535
2000	2.82E-04	2.54E-05***	4.06E-04	2.64E-05***	208196	2.57E-03	2.40E-04***	2.11E-03	2.50E-04***	204498
2001	2.26E-04	2.53E-05***	3.70E-04	2.60E-05***	188917	2.42E-03	2.27E-04***	1.74E-03	2.37E-04***	185282
2002	1.75E-04	2.27E-05***	2.39E-04	2.36E-04***	156517	1.96E-03	2.03E-04***	1.60E-03	2.13E-04***	153833
2003	2.27E-04	2.14E-05***	2.05E-04	2.21E-05***	180919	1.68E-03	2.00E-04***	1.78E-03	2.08E-04***	178101
Bid deal return										
1999	2.68E-04	2.01E-05***	2.37E-04	2.11E-05***	195862	1.61E-03	1.78E-04***	1.91E-03	1.84E-04***	191535
2000	3.55E-04	2.53E-05***	3.74E-04	2.61E-05***	208196	2.36E-03	2.40E-04***	2.59E-03	2.49E-04***	204498
2001	2.70E-04	2.51E-05***	3.45E-04	2.59E-05***	188917	2.24E-03	2.26E-04***	2.31E-03	2.35E-04***	185282
2002	2.02E-04	2.25E-05***	2.09E-04	2.36E-05***	156517	1.78E-03	2.02E-04***	1.97E-03	2.11E-04***	153833
2003	2.44E-04	2.12E-05***	1.92E-04	2.20E-05***	180919	1.50E-03	2.00E-04***	1.96E-03	2.07E-04***	178101

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.14   **Prediction: EUR/USD 5-minute quote return**

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1999	−1.97E-05	3.02E-05	−8.48E-05	3.31E-05**	67676	9.63E-04	7.16E-04	−3.63E-04	7.66E-04	67050
2000	5.43E-05	3.93E-05	2.84E-05	4.29E-05	68196	3.17E-03	1.00E-03**	5.70E-04	1.08E-03	67641
2001	9.74E-05	3.71E-05**	8.46E-05	3.98E-05**	68079	3.33E-03	8.68E-04***	1.38E-03	9.30E-04	67585
2002	9.04E-05	2.98E-05**	9.70E-05	3.29E-05***	67116	1.28E-03	6.98E-04*	1.94E-03	7.43E-04***	66771
2003	1.04E-04	3.34E-05**	9.89E-05	3.63E-05***	59787	2.12E-03	8.80E-04*	4.55E-03	9.62E-04***	59587
Ask deal return										
1999	3.45E-05	3.06E-05	−1.96E-05	3.35E-05	67676	1.70E-03	7.25E-04*	2.54E-05	7.77E-04	67050
2000	8.48E-05	3.96E-05*	6.74E-05	4.32E-05	68196	3.43E-03	1.01E-03**	7.84E-04	1.09E-03	67641
2001	1.24E-04	3.74E-05**	1.27E-04	4.01E-05***	68079	3.64E-03	8.76E-04***	1.63E-03	9.40E-04*	67585
2002	1.13E-04	3.01E-05***	1.22E-04	3.32E-05***	67116	1.55E-03	7.05E-04*	1.99E-03	7.50E-04***	66771
2003	1.30E-04	3.37E-05***	1.19E-04	3.66E-05***	50787	2.27E-03	8.87E-04*	4.86E-03	9.70E-04***	59587
Bid deal return										
1999	1.23E-05	3.04E-05	−5.49E-05	3.34E-05	67676	1.14E-03	7.22E-04	1.19E-04	7.72E-04	67050
2000	9.25E-05	3.95E-05*	6.49E-05	4.31E-05	68196	3.71E-03	1.01E-03***	1.14E-03	1.09E-03	67641
2001	1.39E-04	3.74E-05***	1.15E-04	4.02E-05***	68079	3.83E-03	8.75E-04***	1.87E-03	9.38E-04**	67585
2002	1.13E-04	3.00E-05***	1.19E-04	3.31E-05***	67116	1.60E-03	7.04E-04*	2.44E-03	7.49E-04***	66771
2003	1.15E-04	3.36E-05**	1.17E-04	3.65E-05***	59787	2.50E-03	8.84E-04**	4.80E-03	9.67E-04***	59587

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.   *Note:* ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.15   Prediction: EUR/USD 15-minute quote return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1999	-9.99E-05	4.87E-05**	-8.02E-05	5.80E-05	24089	-1.41E-04	2.85E-03	-2.48E-03	3.24E-03	24058
2000	-3.20E-05	6.18E-05	-1.73E-04	7.34E-05**	24325	8.77E-04	4.01E-03	-1.12E-03	4.48E-03	24305
2001	-7.52E-05	5.86E-05	1.60E-04	6.70E-05**	24338	1.85E-03	3.45E-03	7.08E-04	3.93E-03	24317
2002	6.25E-05	4.59E-05	-1.32E-04	5.52E-05**	24372	-1.20E-03	2.89E-03	1.08E-03	3.08E-03	24352
2003	5.70E-05	5.47E-05	-2.21E-05	6.27E-05	20389	5.92E-04	4.24E-03	9.12E-03	4.75E-03*	20385
Ask deal return										
1999	-8.51E-05	4.89E-05*	-6.27E-05	5.82E-05	24089	-3.26E-04	2.86E-03	-2.22E-03	3.26E-03	24058
2000	1.08E-05	6.19E-05	-1.61E-04	7.35E-05**	24325	1.07E-03	4.02E-03	-2.71E-04	4.49E-03	24305
2001	-6.51E-05	5.88E-05	1.58E-04	6.72E-05**	24338	2.03E-03	3.47E-03	6.07E-04	3.94E-03	24317
2002	7.25E-05	4.61E-05	-1.24E-04	5.53E-05**	24372	-1.05E-03	2.90E-03	1.22E-03	3.09E-03	24352
2003	6.57E-05	5.48E-05	-2.25E-05	6.29E-05	20389	4.68E-04	4.25E-03	9.55E-03	4.76E-03**	20385
Bid deal return										
1999	-9.12E-05	4.89E-05*	-7.06E-05	5.82E-05	24089	6.97E-04	2.86E-03	-2.11E-03	3.25E-03	24058
2000	2.12E-06	6.20E-05	-1.63E-04	7.36E-05**	24325	1.35E-03	4.02E-03	-1.35E-03	4.49E-03	24305
2001	-6.47E-05	5.88E-05	1.83E-04	6.72E-05***	24338	2.14E-03	3.48E-03	1.49E-03	3.95E-03	24317
2002	6.53E-05	4.60E-05	-1.27E-04	5.53E-05**	24372	-8.30E-04	2.90E-03	1.39E-03	3.09E-03	24352
2003	5.70E-05	5.48E-05	-1.31E-05	6.28E-05	20389	1.17E-03	4.25E-03	9.16E-03	4.76E-03*	20385

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.   *Note:* ***, ** and * indicate the significance at 1, 5, 10%, respectively.

Table 6.16   Prediction: EUR/USD 30-minute quote return

	netdeal					ndr				
	ndplus	s.e.	ndminus	s.e.	NOB	ndplus	s.e.	ndminus	s.e.	NOB
Log middle price										
1999	-8.87E-05	6.69E-05	-1.09E-04	8.44E-05	11938	-6.29E-04	7.69E-03	-1.22E-02	9.04E-03	11934
2000	-1.89E-04	8.39E-05**	-3.66E-04	1.07E-04***	12063	-1.23E-03	1.08E-02	-2.20E-02	1.28E-02*	12061
2001	-7.34E-05	7.94E-05	1.03E-04	9.56E-05	12077	-5.29E-03	9.62E-03	-2.48E-03	1.12E-02	12076
2002	-1.09E-04	6.22E-05*	-4.30E-05	8.07E-05	12123	-1.32E-02	7.95E-03*	-3.92E-03	8.67E-03	12118
2003	3.71E-05	7.49E-05	-5.32E-05	9.26E-05	10058	-1.95E-02	1.18E-02	1.42E-02	1.38E-02	10058
Ask deal return										
1999	-7.93E-05	6.70E-05	-1.00E-04	8.44E-05	11938	-5.23E-04	7.70E-03	-1.01E-02	9.05E-03	11934
2000	-1.74E-04	8.40E-05**	-3.52E-04	1.07E-04***	12063	-7.42E-04	1.08E-02	-2.11E-02	1.28E-02	12061
2001	-6.56E-05	7.97E-05	9.71E-05	9.59E-05	12077	-3.44E-03	9.64E-03	-3.44E-03	1.13E-02	12076
2002	-1.03E-04	6.24E-05*	-3.87E-05	8.09E-05	12123	-1.27E-02	7.96E-03	-3.59E-03	8.69E-03	12118
2003	6.55E-06	7.49E-05	-5.59E-05	9.27E-05	10058	-2.03E-02	1.18E-02*	1.38E-02	1.38E-02	10058
Bid deal return										
1999	-8.69E-05	6.71E-05	-1.05E-04	8.46E-05	11938	-5.25E-05	7.71E-03	-1.38E-02	9.07E-03	11934
2000	-1.94E-04	8.41E-05**	-3.67E-04	1.07E-04***	12063	-1.00E-03	1.08E-02	-2.23E-02	1.28E-02*	12061
2001	-7.22E-05	7.96E-05	1.18E-04	9.59E-05	12077	-6.30E-03	9.65E-03	-7.85E-04	1.13E-02	12076
2002	-1.09E-04	6.23E-05*	-4.23E-05	8.08E-05	12123	-1.32E-02	7.96E-03*	-3.82E-03	8.68E-03	12118
2003	5.51E-06	7.50E-05	-4.61E-05	9.28E-05	10058	-1.81E-02	1.19E-02	1.52E-02	1.39E-02	10058

Note: ***, ** and * indicate the significance at 1, 5, 10%, respectively.

sense, in time aggregation more coarse than 30 minutes, it would be very difficult to refute a hypothesis that the exchange rate movement is a random walk. What is new here is that there exists a time window, albeit a short period, that the movement is predictable if the right information, which some market participants are able to gather, is available in real time.

6.4   Measuring the Lag Structure of Price Impacts

The preceding section did not test exactly how long the predictable power may persist. In this section, the lagged effects are measured cumulatively so that how long effects may persist can be estimated more precisely. In other words, the estimation will answer a question: How long the order flow information will remain valuable. In order to examine the cumulative effect of order flows on the exchange rate changes, the following specification with the 1-minute frequency is adopted:

(8) $$\Delta s_t = \alpha + \sum_{i=0}^{30} \beta_i ndr_{t-i} + \gamma_i \Delta s_{t-i} + \upsilon_t$$

In this specification, the contemporaneous effect β_0 is also included, based on the presumption that order flows Granger-cause the price movement. The past 1-minute effect of the transaction on the current price movement is captured by $\beta_0 + \beta_1$, and the past 14-minute effect is expressed as $\beta_0 + \beta_1 + \beta_2 + \beta_3 + \ldots + \beta_{14}$. We calculate the price impact up to 30 minutes.

In estimating equation (8), again, we use three deal returns (midpoint of the deal-ask and the deal-bid price, deal-ask price, and deal-bid price) for Δs, where *ndr* denotes the *netdeal ratio*.[13] Lagged independent variables (up to thirty lags) are also included in the estimation. The calculated price impact defined as $\Sigma_{i=0}^{p} \beta_i$ (p equals up to 30) and associated standard errors are estimated for each of the three candidate return variables and a currency pair. The estimated cumulative price impact with one standard deviation will be examined below.

The price impact, the sum of β_i, is expected to be positive if order flows have predictable power up to the ith minute. For example, if the number of deals done on the ask-side exceeds the number of deals done on the bid-side for USD/JPY, the USD will appreciate *vis-à-vis* the Japanese yen due to more buyer initiated trades occurred. Therefore, *ndr* is positively associated with the returns.

3.4.1   Results

Results are summarized in figures 6.2–6.7. Figures 6.2–6.4 show the price impact of USD/JPY and figures 6.5–6.7 show the result of EUR/USD.

13. Since we do not see a large difference in estimation results of equations through (2) to (7), the estimation in this section was conducted with explanatory variable of *netdeal ratio* only.
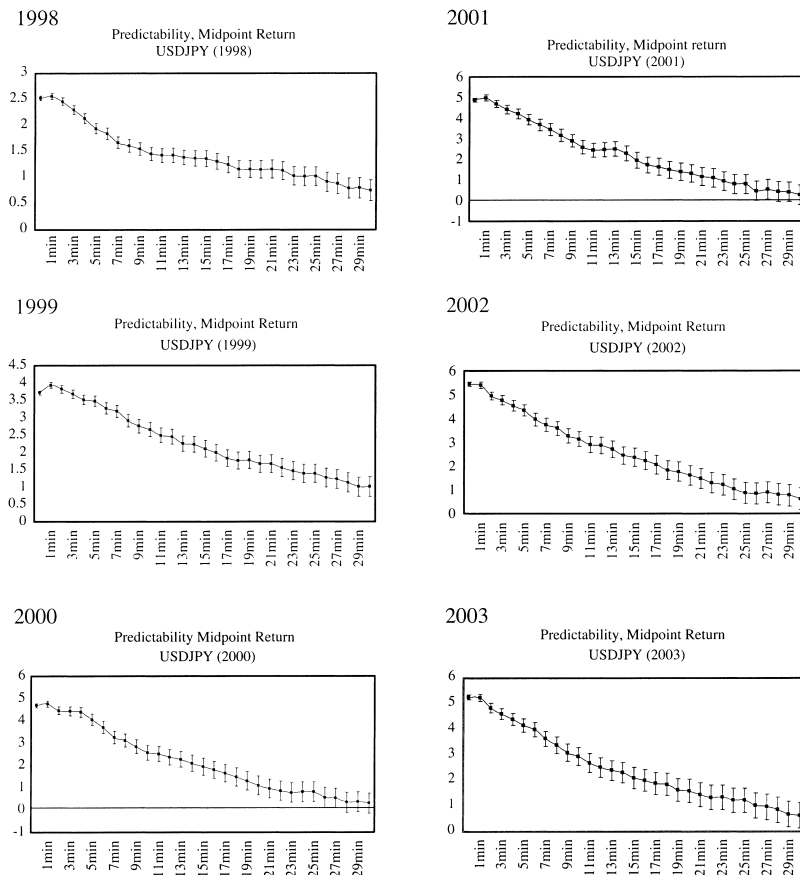
1998

Predictability, Midpoint Return
USDJPY (1998)

2001

Predictability, Midpoint return
USDJPY (2001)

1999

Predictability, Midpoint Return
USDJPY (1999)

2002

Predictability, Midpoint Return
USDJPY (2002)

2000

Predictability Midpoint Return
USDJPY (2000)

2003

Predictability, Midpoint Return
USDJPY (2003)

Fig. 6.2   USDJPY: Midpoint deal return

In each figure, the horizontal axis shows the duration from 0 minutes to 30 minutes, and the vertical axis shows the price impact with bars of one standard error. The price impact is not significantly different from zero when vertical bars of s.e. cross the horizontal axis of zero. Overall, the contemporaneous effects are significantly positive regardless of currencies, definition of returns (midpoint returns, bid-side deal returns, or ask-side deal returns), or sample years.

Figures 6.2–6.4 summarize the price impact of order flows on various measures of returns of USD/JPY. Figure 6.2 shows the price impact on midpoint returns. Overall, the contemporaneous price impact (0 minutes) is very large. In some years, the 1-minute period has the peak, and then the cumulative price impact gradually decreases, although it remains significantly positive even after 30 minutes. There is no significant difference in

1998

Predictability, Deal Bid Return
USDJPY (1998)

2001

Predictability, Deal Bid return
USDJPY (2001)

1999

Predictability, Deal Bid Return
USDJPY (1999)

2002

Predictability, Deal Bid Return
USDJPY (2002)

2000

Predictability Deal Bid Return
USDJPY (2000)

2003

Predictability, Deal Bid Return
USDJPY (2003)
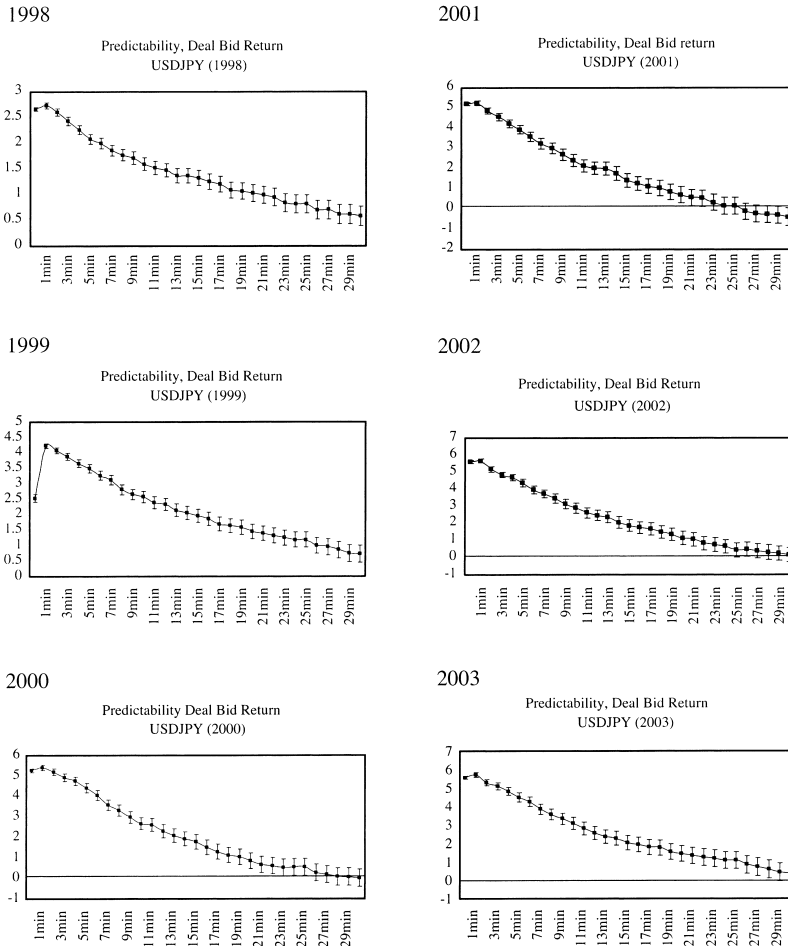
Fig. 6.3   USDJPY: Deal bid return

the price impact patterns over the years. Estimation with bid-side deal re-
turns and ask-side deal returns are shown in figures 6.3 and 6.4, respec-
tively. The size of the contemporaneous price impact (0 minutes) varies
across years, but they are all positive and significant. The cumulative price
impact at 1 minute later is the highest, and then the price impact gradually
decreases. In some years, price impact remains significantly positive after
30 minutes, and in other years, it becomes insignificant at around 25–30
minutes. For bid-side deal returns, price impact becomes insignificant
around 25–30 minutes in 2000, 2001, 2002 and 2003, as shown in figure 6.3.
For ask-side deal returns, price impact becomes insignificant around
28–30 minutes only in 2003, as shown in figure 6.4. For USD/JPY deals, es-

1998   2001

1999   2002

2000   2003
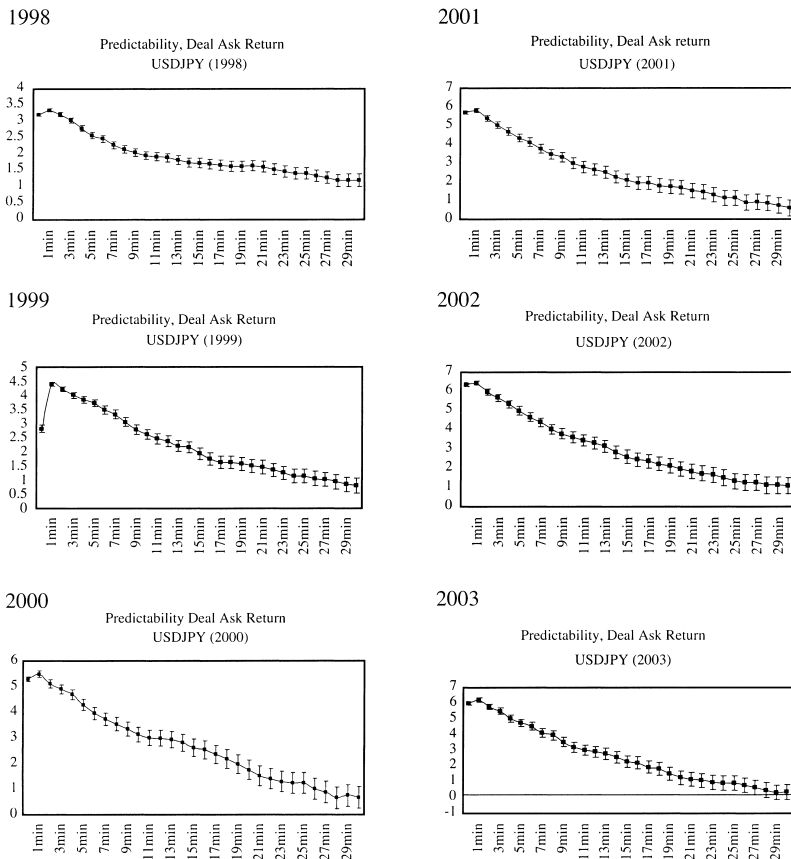
Fig. 6.4   USDJPY: Deal ASK return

timation results show that most of the price impact remains significantly positive after 30 minutes.

Figures 6.5–6.7 show the price impact of order flows on various measures of returns on EUR/USD. Results are mostly the same as the USD/JPY with slight differences. In some years, price impact appears significantly negative at higher lags at around 26–30 minutes. For the midpoint returns, in figure 6.5, the contemporaneous impact is small but positive, and the past-one-minute impact is the largest. Then price impact gradually decreases—but remains significant even at 30 minutes in 1999 and in 2000. Price impact becomes insignificant at 26 minutes in 2001, and significantly negative at around 28 minutes in 2002 and 2003.

Figures 6.6 and 6.7 show the price impact for bid-side deal returns and ask-side deal returns. For bid-side deal returns, price impact remains sig-

1999

Predictability, Midpoint Return

EURUSD (1999)

2002

Predictability, Midpoint Return

EURUSD (2002)

2000

Predictability Midpoint Return

EURUSD (2000)

2003

Predictability, Midpoint Return

EurUSD (2003)

2001

Predictability, Midpoint return
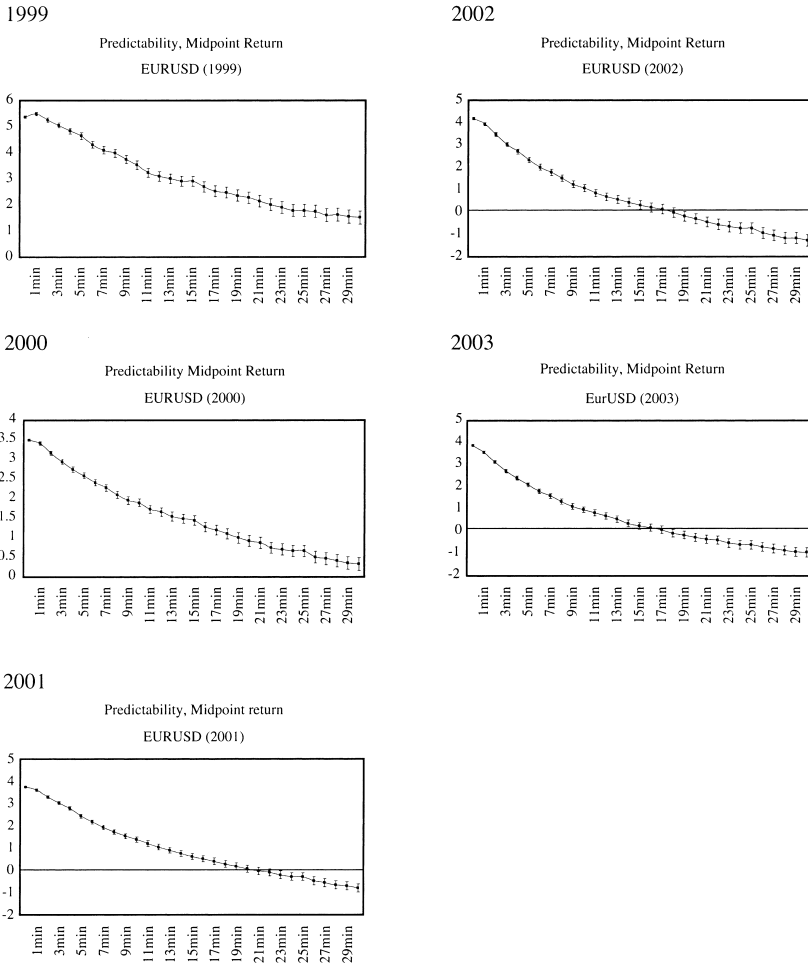
EURUSD (2001)

Fig. 6.5   EURUSD: Midpoint deal return

nificant at 30 minutes in 1999 and 2000, whereas it becomes significantly negative around 26 minutes in 2001 and after. For ask-side deal returns, price impact is significant for 30 minutes in 1999, becomes insignificant at 28 minutes in 2000, and becomes significantly negative after 2001.

In summary, the duration of positively significant returns following order flows has become shorter recently. This may be due to advances in technical trading and computer programming, which results in ever short-lived profit opportunities. For USD/JPY, the impact remains significant around 25 minutes (bid-side deal) and 28 minutes (ask-side deal). For EUR/USD, the price impact becomes significantly negative in recent years.

1999

Predictability, Deal Bid Return
EURUSD (1999)

2002

Predictability, Deal Bid Return
EURUSD (2002)

2000

Predictability Deal Bid Return
EURUSD (2000)

2003

Predictability, Deal Bid Return
EurUSD (2003)

2001

Predictability, Deal Bid return
EURUSD (2001)
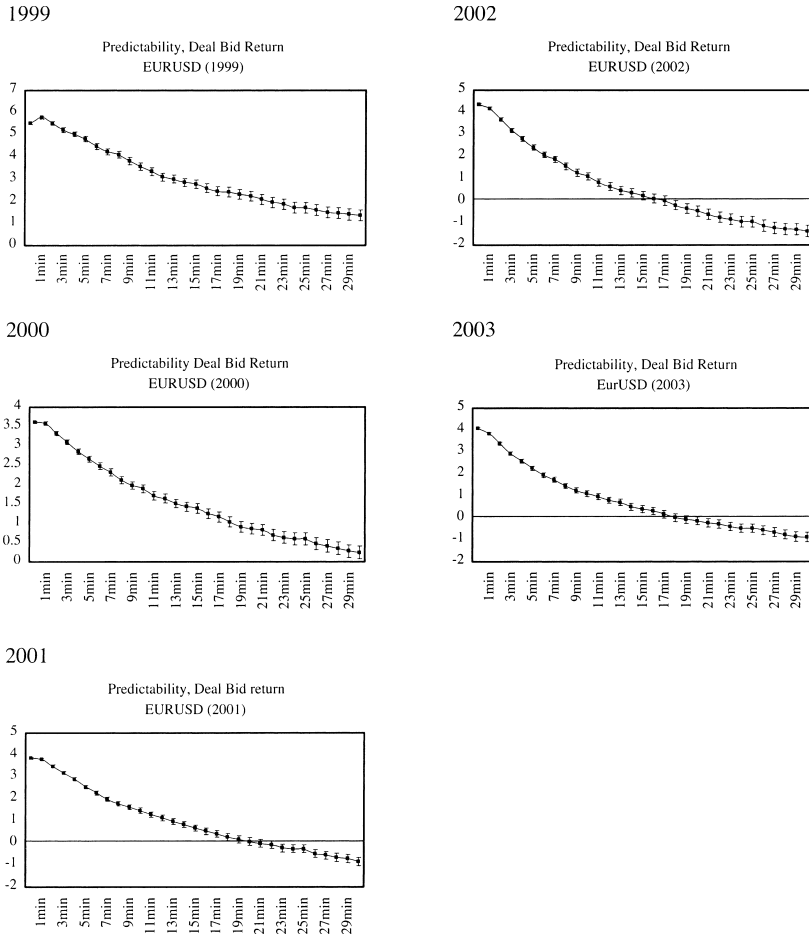
Fig. 6.6   EURUSD: Deal bid return

6.5   Conclusion

We examine the price impact of order flows using the transaction data recorded in the electronic broking system of the both USD/JPY and EUR/USD spot foreign exchange markets. At the 1-minute and 5-minute frequencies, our results show a strong predictive power of order flows for future exchange rate movement, whereas we fail to find any predictability at the half-hour window. In some circumstances, private information in terms of order flows are valuable in real time, but such information is very short-lived.

These findings suggest some profit opportunities if one has detailed information of the second-to-second deal counts/deal volumes in real time. This may explain why the private institutions spend millions of dollars to

1999

Predictability, Deal Ask Return
EURUSD (1999)

2002

Predictability, Deal Ask Return
EURUSD (2002)

2000

Predictability Deal Ask Return
EURUSD (2000)

2003

Predictability, Deal Ask Return
EurUSD (2003)

2001

Predictability, Deal Ask return
EURUSD (2001)
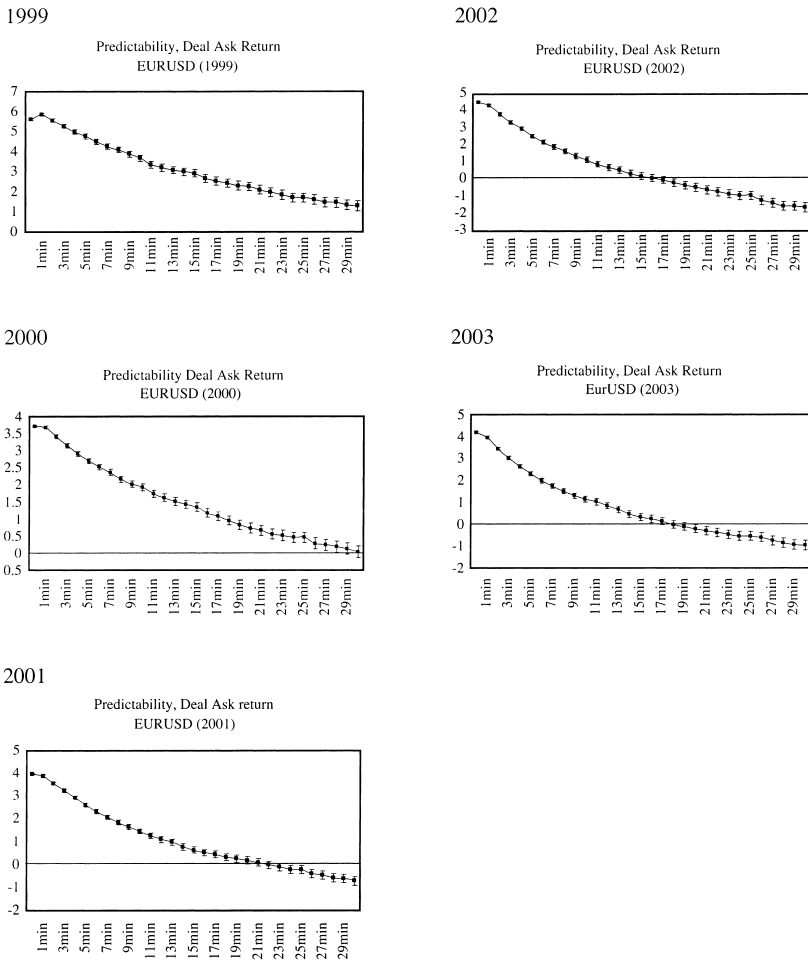
Fig. 6.7   EURUSD: Deal ask return

gather real time information and develop a model to extract buy and sell signals.

Although we found some evidence that price movements are predictable given trades information a minute earlier, this does not necessarily mean that there was a profitable opportunity. The estimation was done for a whole sample, and predictability is tested as an in-sample exercise. To show that profitable opportunity did exist, the exercise has to be done as out-of-sample simulations, taking into account the bid-ask spread, price movements in the preceding minutes, and other information, as well as order flows. A task of more sophisticated out-of-sample simulations is left for future research.

Appendix

Table 6A.1   Summary statistics of nd^{plus} and nd^{minus} of USD/JPY

Year			1 min				5 min			
			Mean	s.d.	Min	Max	Mean	s.d.	Min	Max
1998	ndplus	(netab)	1.230	2.113	0	24	3.633	5.629	0	57
	ndminus	(netab)	-1.079	1.983	-23	0	-2.644	4.714	-49	0
	ndplus	(ndr)	0.276	0.372	0	1	0.162	0.238	0	1
	ndminus	(ndr)	-0.234	0.354	-1	0	-0.125	0.217	-1	0
1999	ndplus	(netab)	1.140	2.000	0	23	3.361	5.292	0	57
	ndminus	(netab)	-1.025	1.877	-24	0	-2.467	4.433	-49	0
	ndplus	(ndr)	0.272	0.372	0	1	0.160	0.239	0	1
	ndminus	(ndr)	-0.234	0.355	-1	0	-0.125	0.220	-1	0
2000	ndplus	(netab)	0.934	1.705	0	21	2.693	4.370	0	49
	ndminus	(netab)	-0.931	1.693	-23	0	-2.260	3.978	-63	0
	ndplus	(ndr)	0.280	0.385	0	1	0.161	0.248	0	1
	ndminus	(ndr)	-0.255	0.374	-1	0	-0.140	0.237	-1	0
2001	ndplus	(netab)	0.980	1.763	0	21	2.891	4.585	0	43
	ndminus	(netab)	-0.934	1.708	-20	0	-2.243	4.005	-44	0
	ndplus	(ndr)	0.279	0.381	0	1	0.165	0.251	0	1
	ndminus	(ndr)	-0.244	0.366	-1	0	-0.133	0.233	-1	0
2002	ndplus	(netab)	1.011	1.823	0	21	2.926	4.690	0	55
	ndminus	(netab)	-0.980	1.786	-23	0	-2.353	4.183	-51	0
	ndplus	(ndr)	0.274	0.378	0	1	0.160	0.247	0	1
	ndminus	(ndr)	-0.243	0.364	-1	0	-0.132	0.230	-1	0
2003	ndplus	(netab)	0.986	1.764	0	23	2.812	4.487	0	45
	ndminus	(netab)	-0.954	1.733	-27	0	-2.255	4.029	-59	0
	ndplus	(ndr)	0.270	0.375	0	1	0.153	0.236	0	1
	ndminus	(ndr)	-0.242	0.363	-1	0	-0.126	0.221	-1	0

Table 6A.2   Summary statistics of nd^{plus} and nd^{minus} of EUR/USD

		1 min				5 min			
		Mean	s.d.	Min	Max	Mean	s.d.	Min	Max
1999	ndplus (netab)	1.159	2.159	0	25	3.146	5.433	0	62
	ndminus (netab)	-1.161	2.150	-27	0	-2.656	4.977	-55	0
	ndplus (ndr)	0.249	0.359	0	1	0.150	0.246	0	1
	ndminus (ndr)	-0.226	0.348	-1	0	-0.127	0.229	-1	0
2000	ndplus (netab)	1.216	2.237	0	30	3.276	5.600	0	55
	ndminus (netab)	-1.217	2.223	-27	0	-2.768	5.138	-51	0
	ndplus (ndr)	0.234	0.346	0	1	0.141	0.236	0	1
	ndminus (ndr)	-0.212	0.335	-1	0	-0.118	0.219	-1	0
2001	ndplus (netab)	1.131	2.081	0	24	2.980	5.056	0	52
	ndminus (netab)	-1.144	2.096	-24	0	-2.526	4.709	-52	0
	ndplus (ndr)	0.239	0.352	0	1	0.140	0.234	0	1
	ndminus (ndr)	-0.215	0.340	-1	0	-0.118	0.220	-1	0
2002	ndplus (netab)	1.116	2.046	0	21	2.948	4.952	0	47
	ndminus (netab)	-1.122	2.033	-25	0	-2.428	4.477	-52	0
	ndplus (ndr)	0.244	0.357	0	1	0.140	0.232	0	1
	ndminus (ndr)	-0.222	0.347	-1	0	-0.119	0.221	-1	0
2003	ndplus (netab)	1.260	2.205	0	23	3.274	5.331	0	48
	ndminus (netab)	-1.232	2.175	-27	0	-2.760	4.899	-51	0
	ndplus (ndr)	0.219	0.334	0	1	0.121	0.205	0	1
	ndminus (ndr)	-0.199	0.322	-1	0	-0.101	0.189	-1	0

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————. 2006. Intra-day seasonality in activities of the foreign exchange markets: Evidence from the electronic broking system. *Journal of the Japanese and International Economies* 20 (4): 637–64.

Ito, T., R. K. Lyons, and M. T. Melvin. 1998. Is there private information in the FX market? The Tokyo experiment. *The Journal of Finance* LIII (3): 1111–30.

Lyons, R. 1995. Tests of microstructural hypotheses in the foreign exchange market. *Journal of Financial Economics* 39:321–51.

Lyons, R. K. 1996. Foreign exchange volume: Sound and fury signifying nothing? In *The microstructure of foreign exchange markets,* ed. J. A. Frankel, G. Galli, and A. Giovanni, 183–205. Chicago: The University of Chicago Press.

Lyons, R. 1997. A simultaneous trade model of the foreign exchange hot potato. *Journal of International Economics* 42:275–98.

Lyons, R. 1998. Profits and position control: A week of FX dealing. *Journal of International Money and Finance* 17:97–115.

Lyons, R. 2001. *The microstructure approach to exchange rates.* Cambridge, MA: MIT Press.

Lyons, R. K., and M. J. Moore. 2005. An information approach to international currencies. NBER Working Paper no. 11220. Cambridge, MA: National Bureau of Economic Research, March.

Comment   Eli Remolona

This is a very nice empirical microstructure chapter. It is the latest in a series of excellent papers by Taka Ito and various coauthors. The chapter is especially interesting because the market it looks at is one in which the microstructure has changed quite significantly. The market in question is the interdealer market for the world's three major currencies, namely the U.S. dollar, the Japanese yen, and the euro. For this study, Ito and Hashimoto have been able to collect a large amount of high-frequency data, even more than what your typical market microstructure paper would have. Given the number of observations they bring to bear on the analysis, almost any phenomenon the authors wish to find should be evident in the data.

At root, the chapter is about the information content of trades. Here the authors ask two basic questions. First, do trades predict prices? Second, does intervention in the currency market by the Bank of Japan affect the results?

The data are from EBS, which is the electronic broker system that is now used for the bulk of interdealer trades in the U.S. dollar, Japanese yen, and euro. For trades between the dollar and the yen, the authors look at the period from January 1998 to October 2003, and for trades between the euro

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and the dollar, they look at the period from January 1999 to October 2003. The euro, of course, did not exist before January 1999.

For purposes of analysis, rather than analyzing every single trade, the authors aggregate the trades into four very short windows: one minute, five minutes, fifteen minutes and thirty minutes. For each of these windows, they create a proxy for order flows, which is the number of bid deals minus the number of ask deals. This proxy is not controversial; it is the way order flows tend to be constructed in the market microstructure literature.

The basic methodology is to regress currency returns on net-order flows for different windows and for up to ten lags. Days during which the Bank of Japan intervened are distinguished from other days. For robustness, the authors compute currency returns in three ways: based on midpoints between bid and ask quotes, based on just-bid prices, and based on just-ask prices. The different definitions of return seem to produce the same results.

The results are interesting. Order flow predicts returns at one-minute and five-minute horizons but not at thirty-minute horizons. On intervention days, that predictability shortens to one minute. The effect of intervention seems to be to induce lagged price adjustment.

An important question that the authors leave unanswered is whether the change in market microstructure induced by EBS matters. Prior to the advent of EBS, currency dealers traded largely bilaterally through voice brokers. They could therefore not easily observe trades that did not involve themselves. With EBS, dealers see what is going on in almost the entire interdealer market, although they may not know the identities of the counterparties to a given trade.

Lyons (1997) has described the trading activity in the inter-dealer currency market as *hot-potato* trading, in which dealers quickly follow a customer trade with trades with other dealers so as to square their position as soon as possible. When Evans and Lyons (2005) looked at the market with electronic trading already in place, they found that order flow helps predict prices at the one-month horizon, a result that seems to be different from that of Ito and Hashimoto. More recently, Berger and colleagues (2005) use EBS data and find no evidence that trades predict prices at any horizon, again a result that seems to be at odds with those of Ito and Hashimoto. Hence, a question the authors should try to answer is how does one reconcile these seemingly disparate results?

It would also be helpful for the authors to try to shed light on the question of what sorts of information are supposed to be conveyed by order flows that allow them to predict price changes up to the five-minute horizon? In equity markets, the empirical literature suggests that there are trades that convey private information, and this information is what allows trades to move prices. By contrast, Fleming and Remolona (1999) show that the sharpest price movements in U.S. Treasury markets are caused by releases of public macroeconomic information, and these price movements

need not be accompanied by trading activity. Berger and colleagues (2005) found something that is still different in currency markets. Here order flow seems to be associated with macroeconomic announcements. Hence, the big unasked question arising from the results of Ito and Hashimoto is what information do currency dealers obtain that seems to remain relevant for five minutes?

References

Evans, M. D. D., and R. K. Lyons. 2005. Do currency markets absorb news quickly? *Journal of International Money and Finance* 24: 197–217.

Fleming, M., and E. Remolona. 1999. Price formation and liquidity in the U.S. treasury market: The response to public information. *Journal of Finance* LIV(5): 1901–15.