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Did the Electronic Trading System Make the Foreign Exchange Market More Efficient?

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Abstract:

This paper examines the effects of introducing the electronic trading system (EBS) on the foreign exchange market, the biggest financial market in the world where trading occurs through many dealers. We find that increasing transparency leads to an increase in informational efficiency, an important aspect of market quality. However, informed dealers are found to quote less aggressively in the more transparent market. Overall, we conclude that semi-transparency raises market efficiency in general, but that it is the uninformed dealers who benefit more from this increased efficiency.

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1. Introduction

The foreign exchange market is the largest financial market in the world with a daily turnover of $US 3.2 trillion.[1] It is a typical dealership market where dealers around the world compete with each other for customers. For inter-dealer trading, the dealers also trade with each other in order to share the risk of holding unbalanced currency inventories, and to speculate. This market's institutional arrangement differs from that of a centralized auction market (such as the New York Stock Exchange), where individuals known as specialists make the market and coordinate the trading process.

Transparency is a key aspect of any financial market. The main idea of market microstructure studies is that information aggregation in the market leads to price discovery. For the foreign exchange market, full transparency includes revealing the limit order book and best offer price pre-trade, and transaction price and quantity post-trade. Traditionally, the foreign exchange market has relied on bilateral phone-based trading platform, in which access to the market information is very limited. Two main electronic systems, the Reuters System and the Electronic Brokering System, were introduced in 04/1992 and 10/1993 respectively. The new systems reveal only the offer price before trade and transaction price after trade, and account for most of the transactions in the market. In this sense, the new electronic trading systems transformed the foreign exchange market from almost opaque to semi-transparent. As the EBS is the primary liquidity source for EUR/USD (DEM/USD before 1999), the effect of EBS on the market should be more significant than that of Reuters, which has been confirmed by Ding and Hiltrop (2009). Thus, this paper only focuses on the EBS, and would consider only 10/1993 as when the electronic system was introduced.

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[1] BIS triennial survey, 2008.

Dealers, the players of the market, are usually classified as big (informed) dealers and small (uninformed) dealers. Big dealers, such as big banks, possess relative information advantage because of their market power and connections with insiders. Small dealers, who could even be individuals, obviously lack the same information sources. Intuitively, in a completely transparent market, informed dealers would hesitate to trade. This is because dealers reveal their known information while trading, and big dealers do not want to lose their information advantage. On the other hand, in a completely opaque market, uninformed dealers will be taken advantage of and are thus unwilling to trade as well. Both extremes impede market liquidity and result in less trading activities. A trade-off exists between transparency and market quality, and some semi-transparency level should be the optimal. By examining the impact of the electronic trading systems on the foreign exchange market, we will be able to ascertain whether the change from opacity to semi-transparency has indeed increased market efficiency. No research to date has done such an empirical test, thus our paper contributes to the literature by providing the first investigation on a semi-transparency event on a dealership market.

We find that the information efficiency increased after the system was introduced, by testing through first-order return autocorrelation. We also determine the impact on the big and small dealer groups by measuring the relative contributions of each dealer group to the price discovery process, and find that big dealers quoted relatively less aggressively after the system was introduced. Overall, we conclude that the semi-transparency raises market efficiency in general, but that it is the uninformed dealers who benefit more from this increased efficiency.

The remainder of the paper is structured as follows: Section 2 provides a brief survey of the literature; Section 3 introduces in detail the data we use in the study; Section 4 tests the first and second hypotheses above, analyzes the results and performs additional robustness tests; Section 5 concludes.

2. Literature Review

Theoretical studies on the dealership market lean towards semi-transparency. Biais (1993) predicts that pre-trade transparency increases both market efficiency and liquidity. Lyons (1996) suggests that the disclosure of order flow will make informed dealers lose their information advantage, thus these dealers would hesitate to trade, which decreases market liquidity. He argues that semi-transparency should be optimal for market liquidity. Naik, Nueberger and Viswanathan (1999) provide another trade-off between transparency and market liquidity. They show that greater transparency can reduce inventory holding costs, but increase price revision risk. The nondisclosure of the first-stage trade details allows the market maker who receives the order first to profit from the learned information.

Existing empirical results are mixed, partly because most of these studies focus on full transparency markets. In the NASDAQ, Harris and Schultz (1997) find that in the anonymous Small Order Execution System, market makers show wider bid-ask spreads compared with the regular non-anonymous dealer markets. Such a finding suggests that increasing identity transparency increases market liquidity. Chung and Chuwonganant (2009) examine how the introduction of SuperMontage, which increases pre-trade trade transparency by displaying the limit order book, affects the NASDAQ. They find the

transparency change improves market and execution quality. In bonds market, which is another dealership market, Bessembinder, Maxwell, and Venkataraman (2006) find significant reductions in institutional execution costs after the initiation of the Trade Reporting and Compliance Engine (TRACE) reporting system which increases post-trade transparency. Hendershott and Jones (2005) study a change to a less transparent trading system at Island, an Electronic Communications Network (ECN). After stopping displaying its limit order book in its most liquid products to all market participants, the Island is found to have higher trading costs and loses market share. In contrast, Goldstein, Hotchkiss, and Sirri (2007) show that except for very large trades, spreads on bonds whose prices become more transparent decline relative to bonds that experience no change in transparency.

Many other studies focus on auction market. The results are inconclusive. For example, Boehmer, Saar, and Yu (2005) examine the effect of increasing pre-trade transparency by introducing OpenBook service on the New York Stock Exchange (NYSE), which reveals limit order book in the market and hence increases pre-trade order transparency. They show that greater pre-trade transparency led to higher liquidity and greater informational efficiency of price. In contrast, Gemmill (1996) finds no evidence of liquidity change when the London Stock Exchange reduces post-trade transparency by delaying the publication of prices for block trades. The previous discussion on the difference between auction and dealership markets—mainly, the absolute information advantage of specialists, and smaller degree of competition for information in auction market, versus the decentralized nature and greater competition for information found in dealership market—would shed light on the different results obtained in the auction

market. It is also for this reason that we base our predictions along those of dealership market studies.

The literature surveyed above paints the general picture of a trade-off between transparency and market quality in the foreign exchange market. Specifically, the advantage of full and prompt information disclosure is to lower the costs of trading for uninformed dealers. The main disadvantage is that informed market participants would hesitate to trade, so that market liquidity is hurt. I will contribute to the literature by conducting the first empirical study on semi-transparency in a dealership market. The event we study is the introduction of the electronic trading systems that changed the foreign exchange market from almost opaque to semi-transparent. The lack of semi-transparency study on dealership market distinguishes our work from the rest. Furthermore, most of the existing studies do not investigate how different market participants are impacted by the change in market transparency. As we saw earlier, related studies present somewhat mixed results on the impact of semi-transparency, and suggest that greater transparency benefits uninformed dealers at the expense of informed dealers. We therefore propose the following two null hypotheses:

1. Semi-transparency (pre-trade quote transparency and post-trade price transparency) does not affect market efficiency.

2. The impact of semi-transparency is the same for informed dealers and uninformed dealers.

3. Data and Summary Statistics

The ideal data for our tests should contain real transaction data that cover periods

before and after the system was introduced. However, the electronic transaction data currently available, such as the popular ones from the Electronic Brokering System used in many recent studies, do not have dealer identifiers with each transaction, so that the impact on different dealers cannot be tested (that is, we would not be able to test Hypothesis 2). Another restriction is that real transaction data before 1992 are difficult to obtain. Therefore, we use indicative data provided by Olsen Financial. Several studies, such as Goodhart *et. al.* (1996) as well as Chen and Phylaktis (2009), show that the real data and indicative data are almost identical, so we are assured that using indicative data will not fundamentally affect the reliability of our results. Lastly, neither indicative nor real data have transaction volumes. We follow the convention of previous studies, such as Kaul and Sapp (2009), to use quoting frequency as a proxy for transaction volume. Goodhart *et al.* (1996), Chen and Phylaktis (2009), and Danielsson and Payne (2002) also show that indicative quotes frequency and real frequency are highly consistent.

Our data cover all months between 10/1992 – 04/1994. They can be divided into quote data and news data. For each month, the quote data consist of tick-by-tick spot quotes for the Deutsche Mark-U.S. Dollar exchange rate. The bid and ask prices, the date, and the time rounded to the nearest second are also provided for each quote. In addition, each quote has a unique Reuters identifier which specifies the quoting dealer and their location. Before 10/1993, the identifiers are numbers. For instance, code 0043 refers to the CitiBank in New York City. After 10/1993, the identifiers are 4-letter codes. For instance, CITN is the code for the CitiBank in New York City. We use this information to identify the most active participants in the market. Table 5 shows the top 10 dealers ranked on quote frequency throughout our sample period. Following other studies such as

Bollerslev and Domowitz (1993), we exclude weekends and holidays, because of their low and inconsistent trading activity. We define weekends as extending from 20:00 GMT Friday evening (the close of North American markets) until 23:59 GMT Sunday evening (when trading commences in the Far East).

There are numerous data points for each month. Table 1 reports descriptive statistics for quote frequency at 5-minute intervals and raw data of all midquotes. Figure 1 displays daily average midquotes (the average of bid and ask prices), midquote variance, and quote frequency for big and small dealers separately[2]. Note that because there are a number of missing observations in 10/1993, the data do display some discontinuity for that month. The midquotes of big and small dealers, as shown on the first panel of the figure, show almost no difference. This provides a good grounding in our information share estimation in Section 4.2, where we assume that big and small dealers' quotes should not differ substantially. The variance plot shows that big dealers' variance is slightly smaller than small dealers. Also, we can see from the figure that variance decreases, whereas quote frequency increases, after the EBS was introduced. Midquote variances and quote frequencies correspond to market volatility and trading volume, respectively, which are two important aspects of market quality. Although we will not conduct specific tests, the decrease in midquote variances and the increase in quote frequency suggest an improved market quality following the introduction of the system.

To test news effect in the different trading systems, we also obtained news data extracted from Reuters AAMM headline news during the same period. Each news observation includes the date, the time rounded to the nearest second, and a brief sentence

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[2] Here, big dealers are defined as top 5 dealers based on their monthly quoting frequencies. In subsequent sections this definition will be changed.

of the news content. According to Almeida et al (1998) and Anderson et al (2007), various macroeconomic news announcements are found to have significant impact on dealers' quotes. We use a classification similar to theirs and include all news regarding interest rate, inflation rate, unemployment rate, income, spending, retail sales, consumption, GDP, durable goods consumption, payroll, industrial production, CPI and PPI as significant news. Table 3 shows the frequency of the major news in each month, and Figure 2 displays the daily frequency of news (all news) arrivals throughout the period. Both the table and figure show that news frequency increases significantly since late 1993, probably due to the stock market downturn caused by the Peso crisis and tightening monetary policy in the US market during the period.

4. Analysis

4.1 Information Efficiency Test

The basic theory underlying the first hypothesis is the efficient-market hypothesis, which asserts that financial markets are "informationally efficient." This means that prices of traded securities reflect all available information. The foreign exchange market is the largest financial market in the world in terms of transaction volumes, and the traded security is the currency, with the price being the quotes submitted by different dealers at different points in time. Because information is the key in ensuring that the market is efficient, it is natural to expect that the more easily information is transmitted among market participants, the higher the efficiency is.

An efficient market is characterized by a random walk model, applied to the security prices. A random walk model basically says future security prices could not be

determined by past prices. Thus, written in algebraic form, it is:

$$X_t = X_{t-1} + \varepsilon_t, \quad \text{where } X_t \text{ represents the price series}$$

Because X_t is nonstationary, we cannot run model on X_t using the original form. So we run first differences of X_t and its lagged values, then the above equation becomes:

$$\Delta X_t \sim \Delta X_{t-1}, \quad \text{where the coefficient for } \Delta X_{t-1} \text{ would be zero. In other words, if the}$$

market follows a random walk, then current security returns do not predict future returns. Therefore, the key to comparing the market efficiency before and after the system is to compare the coefficients before and after the system, and see which one is closer to zero (and thus follows a random walk model).

As suggested by Kaul and Sapp (2009), if a financial market is efficient, then security returns follows a random walk and its first-order autocorrelation should be zero. Accordingly, if the information incorporation is more efficient in the semi-transparent trading system, autocorrelation coefficient of exchange rate returns should be closer to zero. We use the following specification to test the hypothesis:

$$r_t = \gamma + \rho_1 r_{t-1} + \rho_2 EBS_t r_{t-1} + \rho_3 F_{t-1} r_{t-1} + \rho_4 EBS_t F_{t-1} r_{t-1} + \varepsilon_t$$
$$h_t = a + a\varepsilon_{t-1}^2 + bh_{t-1} + \delta F_{t-1}$$

The subscripts t and t-1 signify that it is a time series process. We pick quotes from our raw data set so that they are five minutes apart from each other, and use the resulting quotes as our series. In the first equation above, r_t is spot exchange rate change, defined

as the first order difference of logarithm spot rate. *EBS* and *F* are system dummy and quote frequency respectively, so F_t is the number of quotes in the *t*-th 5-minute interval. ε_t is a classical error item with variance of h_t. The second equation is a GARCH (1,1) process to account for the time-varying second moment of exchange rate return. Unlike a typical GARCH (1,1) specification, we incorporate the lagged value of *F* because in our framework, quote frequency also has an impact on the variance of exchange rate return.

There are four coefficients in the first equation. Coefficient ρ_1 measures the autocorrelation coefficient before the system was introduced. The system dummy EBS is included to compare the autocorrelations before and after the electronic system, and coefficient ρ_2 reflects such a difference. Autocorrelation of exchange rate return intuitively reflects over or under reaction of the exchange rate change to news. Increasing trading activity usually implies overreaction in the market. We use quote frequency to interact with the lagged returns to reflect this effect. Similar to general autocorrelation part, we also include a system dummy to examine the difference between the effects before and after the new system.

The results are reported in Panel A of Table 2. According to the table, the constant term is not statistically different from zero, which is consistent with the requirement of the random walk model. The coefficient ρ_1 is significantly negative, suggesting price reversal, a typical pattern for high frequency financial data. The coefficient of cross-product of system dummy and lagged return ρ_2 is found to be significantly positive, which implies that the semi-transparent system reduces exchange

rate return autocorrelation and brings it closer to zero. In other words, information efficiency is higher in the new system. The significantly positive ρ_3 implies over-reaction in the market when trading is more active. The negative ρ_4 suggests that this over-reaction decreases in the new trading system. Overall we can see that after the system was introduced, the autocorrelation for returns becomes closer to zero. This agrees with our expectation that the information efficiency increases when the new system facilitates easier information dissemination.

4.2 Price Discovery Efficiency

Flood et al. (1999) argue that due to higher search costs, informed dealers quote more aggressively in opaque market and quote transparency causes slower price discovery. Madhavan (1995) also suggests that participation of informed dealers might be deterred in a more transparent market because greater transparency reduces the effective amount of noise in the market, lowering market liquidity and making prices more sensitive to undisclosed liquidity trades. In Section 4.1, we show that semi-transparency increases price efficiency in the sense that it reduces under or over-reaction to the market news. However, it does not provide any insights into the concern about whether informed dealers might deter their quoting so that some private information might not be released as quickly as in the opaque market, causing slower information incorporation.

According to the research mentioned above, big dealers who possess information advantage should quote more aggressively in the opaque market. Such aggressiveness can be measured by dealers' contribution to the efficient price. We use the concept of information share, introduced by Hasbrouck (1995), to measure each group of dealers'

relative contribution.

Despite the fact that different dealers give different quotes, their quotes should be very close to each other, otherwise arbitrage behavior would eliminate any significant differences among the quotes. In this sense, dealer quotes are cointegrated. Price quotes of big dealers (P_{1t}) and small dealers (P_{2t}) can be written as:

$$P_{1t} = m_t + s_{1t}$$
$$P_{2t} = m_t + s_{2t}$$
(4-1)

where m_t is used in both equations because two prices are driven by the same implicit efficient price (Hasbrouck (2002)). Since price levels are $I(1)$ processes, first order differences of price levels would be $I(0)$ processes. According to the Wold Theorem, any variance stationary time series can be represented in the moving average form. Thus the moving average representation of ΔP_t is given by:

$$\Delta P_t = e_t + \psi_1 e_{t-1} + \psi_2 e_{t-2} + ...$$
(4-2)

where $e_t = [e_{1t}, e_{2t}]$ reflect the innovations in the two groups, and ψ_i are two-by-two matrices. This vector moving average (VMA) model can be simplified as the VECM format:

$$\Delta P_t = \alpha\beta' P_{t-1} + \sum_{j=1}^{k} A_j \Delta P_{t-j} + e_t$$
(4-3)

where $P_t = (P_{1t}, P_{2t})'$ is the two-group price series, α is the error correction vector, β is the cointegrating vector, and e_t consists of innovations. This equation is an elegant simplification of the VMA form and is easier to estimate. The first term on the right hand side represents the long-run equilibrium dynamics, whereas the second term represents

short-run frictions. The residuals term e_t is the innovations term in the quotes, which comprises two vectors of serially uncorrelated disturbances.

To calculate the information share of each group over a particular period, we pick estimated innovations e_t in the target period, which has two columns (corresponding to two groups of price series), and calculate the covariance matrix of the innovations Ω:

$$\Omega = \begin{bmatrix} \sigma_1^{\,2} & \sigma_{1,2} \\ \sigma_{1,2} & \sigma_2^{\,2} \end{bmatrix} \tag{4-4}$$

where $\sigma_1^{\,2}$ and $\sigma_2^{\,2}$ are innovation variances from the two groups, and $\sigma_{1,2}$ is covariance of innovations. Usually the covariance is not zero because there will always be some correlation between the two price series. In our example, we have big dealer and small dealer price series as the two groups, and there is hardly any justification that these two series should be totally uncorrelated. To eliminate the contemporaneous correlations, we employ a Choleski Decomposition on the covariance matrix:

$$\Omega = MM' \tag{4-5}$$

$$\text{where } M = \begin{bmatrix} m_{11} & 0 \\ m_{12} & m_{22} \end{bmatrix}$$

Assuming that $\alpha \perp = (\gamma_1, \gamma_2)'$, then the information shares of the two price series in the target period are:

$$S_1 = \frac{(\gamma_1 m_{11} + \gamma_2 m_{12})^2}{(\gamma_1 m_{11} + \gamma_2 m_{12})^2 + (\gamma_2 m_{22})^2} \tag{4-6}$$

$$S_2 = \frac{(\gamma_2 m_{22})^2}{(\gamma_1 m_{11} + \gamma_2 m_{12})^2 + (\gamma_2 m_{22})^2} \tag{4-7}$$

Notice that S_1 and S_2 sum to 1. Intuitively, they give both groups' percentage

contributions in the price discovery. If the theoretical hypothesis is true, informed (big) dealers' information share should decrease after the electronic trading system.

We use the same set of quote data and news data described before to conduct this test. We look at quotes from each trading day (weekdays) and pick quotes (mid of bid-ask prices) every five minutes from 8:00am to 20:00pm GMT daily. We pick these hours because European and North American markets are open during these hours and they usually have the most frequent trading activities and news releases on any given day. Quotes are picked from the big and the small dealers groups respectively, where big dealers are the top five dealers in terms of quoting frequencies for each month[3].

Before we start the estimation, we conduct a Johansen cointegration test on the big and small dealers' quotes to confirm that they are cointegrated, with cointegrating vector (1,-1), a condition for the method to work. The results are positive. Then, following Sapp (2002), we use Seemingly Unrelated Regression (SUR), which takes into account heteroskedasticity and contemporaneous correlations among innovations, to estimate equation (4-3) to obtain each group's efficient price innovation (e_t). The optimal number of lags in the equation above is determined through Schwarz-Bayesian Information Criterion (BIC), and is found to be j=5.

Recall that the purpose of this section is to test whether informed dealers would quote less aggressively and reveal less information in a more transparent market. Such a pattern, if true, should be most significant when information asymmetry is most severe (i.e. when big dealers have the most information advantages). Chen and Phylaktis (2009) show that big banks have private information advantage especially after major news is released. So we pick the period after major news release as our target period to test

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[3] Different thresholds will be tested later for robustness of the results.

information share change before and after the EBS was introduced.

Again, following Almeida et al. (1998) and Anderson et al. (2007), we define various US and German macroeconomic news as significant news releases, and Table 3 shows how many major news releases are included in our test. We focus on one hour after each significant news release to calculate information share by using equations (4-3) through (4-7). Note that we pick elements from vectors e_t that correspond to the hour after each significant news release, so we obtain information share values for the hour after each significant news release for each month. One hour window is picked because any period shorter than that might not have enough observations to calculate reliable information share[4]. Also, the one hour interval makes major news overlaps quite insignificant, i.e. most significant news release times are more than one hour from each other. This means that when calculating information shares, a certain quote will most likely only belong to one news group.

We test the hypothesis that the information shares of big dealers calculated from these quotes should be smaller after the system was introduced. The information shares are computed for each news release. A simple paired t-test is conducted, and the results are reported in Panel A of Table 4. Big dealers' information share in the new system is significantly lower than in the old opaque system at the 1% level. Figure 3 shows the average information share of each month, with the vertical axis being the information shares for big dealers for each month. The first 12 observations are before the electronic systems were introduced and subsequent observations are after the new system. Apparently, big dealers' contribution to the efficient price decreases after the electronic trading system.

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[4] We will test different window periods longer than 1 hour later to check the robustness of our results.

In addition to major news releases, news arrival frequency is another indicator of information asymmetry. As shown in Chen and Phylaktis (2009), big dealers' information share increases as more news arrive the market. If big dealers quote less aggressively in the electronic trading system, the increase of their information share should decrease. Thus, we have the second specification below:

$$IS_t = \alpha + \beta_1 NA_t + \beta_2 NA_t \cdot EBS_t + \eta_t$$

Information share in this test is calculated based on the quotes for each hour in every trading day. News arrival frequency is also counted based on the corresponding hour.

The results are reported in Panel A of Table 6. The coefficient of news arrival is found to be significantly positive, suggesting that big dealers do have more information advantage and make higher contribution to the price discovery when more news arrives to the market. Meanwhile, the significantly negative coefficient of interaction between news arrival and system dummy says that the increase in price contribution has decreased in the new trading system. This result, along with the result from the first information share test, suggests that the dealers with information advantage do quote less aggressively in the semi-transparent market, which supports the conclusions obtained in Flood et al. (1999) and Madhavan (1995).

4.3 Robust Tests

In the information efficiency test in Section 4.1, although the results are significant, it does not directly imply that the increase in information efficiency was

exactly due to the new system introduced in 10/1993. The EBS dummy variable may simply act as time dummy in an environment where information efficiency gradually increased due to other reasons. To address this concern, we conduct a robustness test by focusing on the months immediately before and after the system was introduced, and performing the same test using data from these months. If this test also returns significant results, it would indicate that the increasing information efficiency was indeed due to the abrupt system change in 10/1993. Because the system change actually started in 09/1993, we use data from 08/1993 and 11/1993 for this test. The results are reported in Panel B of Table 2. Again, all coefficients have the same respective signs with those obtained from the full sample test. The more negative coefficient for lagged return, combined with the more positive coefficient for system dummy interacting with lagged return, implies that even though price reversal is more severe when the sample covers months immediately before and after the EBS was introduced, the system reduces exchange rate return autocorrelation to a greater extent so as to bring it closer to zero (in fact, the net value -0.1035 is closer than -0.1201, the net value under the full test). In other words, the effect is more apparent in this short term test. The same implication could be drawn from the other pair of coefficients. Overall, we can conclude that the new system contributed to an increase in information efficiency.

In Section 4.2, we found significant evidence that information shares of big dealers decreased after the system was introduced. In fact, information share can be affected by two factors. First, how much information advantage the dealer has (i.e. degree of information asymmetry). Second, how much the dealer is willing to reveal her private information through her quotes. The decrease of big dealers' information share detected

by our paper might also be caused by their loss in information advantage, thus the decrease in information share does not necessarily mean that big dealers are not willing to reveal this information in the semi-transparent market. To address this concern, we show that big dealers did not lose their information advantage. The information advantage can be measured by a popular metric in market microstructure literature -- the Probability of Informed Trading (PIN). The PIN is calculated as the ratio of orders from informed traders to the total number of orders. Unlike many applications of the PIN where dealer IDs are unknown and the ratio needs to be estimated, we can explicitly identify informed dealers (usually big dealers) in our data so that each big dealer's PIN can be directly approximated by their quote frequency over the total frequency. This ratio also reflects the actual market share the dealer has. As suggested by FX market microstructure studies such as Evans and Lyons (2002), private information is mainly conveyed through order flow that dealers receive. Thus, intuitively, the bigger transaction volume and market share the dealer has, the more information advantage the dealer has.

Table 5 lists the top 10 dealers for the months before and after 10/1993 with their approximated market shares. It is evident from Table 5 that top banks before the EBS continue to be top banks after the introduction of EBS. In addition, the variation of top 5 dealers' monthly quotes ratios is shown in Figure 4. There is hardly any evidence that the ratios have changed over this period. In fact, they seem to have gone up a little. Therefore, Figure 4 and Table 5 together provide evidence that big dealers' composition and their sheer quoting activities have not changed significantly. This implies that if the information shares for big dealers decrease, it can only be the result of their intentional hiding of information.

In our original test, we define the top 5 banks as big dealers. Although this definition is not totally arbitrary and has empirical rationale, it is somewhat subjective. To test the robustness of our result with respect to this concern, we run the test again with different definitions of big dealers -- the top 10 and top 20 banks as big dealers, respectively. The results obtained from using the top 10 banks (reported in Table 4, Table 6 and Figure 5) are very similar to the previous results. The t-test (Table 4) returns a significant, positive t-statistic, indicating that the monthly average information shares after significant news releases were higher before the system was introduced. In addition, the dummy coefficient, along with other coefficients, for the hourly information share test (Table 6) have the same sign and comparable magnitudes with those obtained when testing with top 5 banks as big dealers.

The results for the top 20 banks (see Table 4, 6 and Figure 6) are different in that the dummy coefficient becomes positive, and so the information share values after the system was introduced are bigger than those before. This is actually not surprising because by switching from top 10 to top 20, we are adding a lot more banks and so the information share values for this group of big banks should increase. Also, by including more banks into our "big dealer" list, the distinction between the big dealers and small dealers becomes less substantial, as does their behavior. These results show that as the threshold for big dealers becomes lower, the effect diminishes, and even changes sign. We conclude that we can see significant decrease in information share values, and thus the intentional hiding of information, for dealers up to the top 10 banks.

In the original test, we calculate the information share for the interval of 1-hour after major news release. The selection of 1-hour is also somewhat subjective. We test

robustness of our results by using different window periods – 1.5 hour and 2 hours. Results are reported in Table 4, 6 and Figure 7, 8. It is clear that the results are robust. Using different window periods paints the same picture as before: significant positive coefficient for news arrival, and significant negative coefficient for the interaction variable. This provides strong empirical support that within a reasonable time period after important news releases, big dealers do have information advantage, but they reveal less of their insider information after the system made the market more transparent.

5. Conclusion

This paper examines the effect of introducing the EBS on the foreign exchange market. The event transformed the market from being almost opaque to semi-transparent. The paper tries to answer whether this change has affected the market efficiency and if so, how different the effect is between informed (big) and uninformed (small) dealers. We tested informational efficiency and price discovery efficiency in order to answer this question.

The paper finds that semi-transparency brought by the new system leads to an increase in information efficiency overall. However, informed dealers tend to reveal less information in the more transparent market, thus contributing less towards the efficient market prices. Several robustness tests are conducted, and the results agree with each other and confirm our conclusions.

Prior to our study, the impact of electronic trading systems on the FX market had not been studied extensively. Even now, further research is necessary in several key areas. Although quoting frequency turns out to be a reliable proxy for volume in our tests, it is

still not as accurate as actual volume data. It would consequently be valuable if future studies retest our hypotheses with real volume data. With actual transaction data, future research can also test how different dealers' monetary welfare change after the new system. Moreover, the current research is limited to the inter-dealer market, but it could be extended to the customer FX market. Such research could, for example, focus on internet trading, which is gaining popularity and changing the information structure in the customer market.

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Table 1: Basic Statistics of Midquotes and 5-min Quote Frequency

	Sample Size	Mean	Standard Deviation	Min	Max
Midquotes	2622458	1.6613	0.0682	1.3895	1.7710
Quote Frequency	93053	28.0338	24.8340	3	311

Table 2: Exchange Rate Return Autocorrelation Test

This table reports the regression results of the equation:

$$r_t = \gamma + \rho_1 r_{t-1} + \rho_2 EBS_t r_{t-1} + \rho_3 F_{t-1} r_{t-1} + \rho_4 EBS_t F_{t-1} r_{t-1} + \varepsilon_t$$

$$h_t = a + a\varepsilon_{t-1}^2 + bh_{t-1} + \delta F_{t-1}$$

Numbers above the parentheses are estimated coefficients and numbers in the parentheses are the corresponding t-statistics. * indicates the coefficient is significant at 5% significance level.

	#obs	Constant	Lagged return	Lagged return*dummy	Number of quotes*lagged return	Number of quotes*Lagged return*dummy
Panel A: full sample						
All dealer	96417	-0.0000 (0)	-0.1951* (-34.15)	0.0750* (68.47)	0.0035* (132.29)	-0.0031* (-10.33)
Panel B: short term						
All dealer	11725	0.0000 (0)	-0.3056* (-20.42)	0.2021* (6.35)	0.0069* (8.13)	-0.0066* (-7.31)

Table 3: Number of Significant News Releases in Each Month

Significant news are US and German macroeconomic news, including news related to GDP, interest rates, inflation, unemployment, income and spending, retail sales, durable goods sales, consumption, industrial production. The news data we use come from Reuters AAMM headline news.

month	92/10	92/11	92/12	93/01	93/02	93/03	93/04	93/05	93/06
frequency	57	56	36	62	43	61	61	62	105
month	93/07	93/08	93/09	93/11	93/12	94/01	94/02	94/03	94/04
frequency	57	41	74	97	128	155	108	154	163

Table 4: T-Test Results

Top 5 dealers for every month in terms of the number of quotes given; same definition applies to other top dealers. * indicates the coefficient is significant at 5% significance level.

	t-statistics	Sample Size	Implications of the results
Panel A: different threshold for big dealers			
Top 5 Dealers	16.8966*	834	The information shares after 93/10 are smaller
Top 10 Dealers	14.7921*	836	The information shares after 93/10 are smaller
Top 20 Dealers	-24.7063*	837	The information shares after 93/10 are bigger
Panel B: different horizon for information share			
1.5 hours Window Period (top 5 dealers)	19.0277 *	834	The information shares after 93/10 are smaller
2 hours Window Period (top 5 dealers)	19.1851 *	834	The information shares after 93/10 are smaller

Table 5: Dealers ranking with quote frequency ratio

This table lists top 10 dealers based on monthly quote frequency. The corresponding ratios are each dealer's quote frequency over total quote frequency, used as proxy for market share and PIN.

Banks	Ratios	Banks	Ratios	Banks	Ratios
04/1993		05/1993		06/1993	
Deutsche Bank	0.0772	Deutsche Bank	0.0773	Deutsche Bank	0.0794
BHF Bank	0.0647	Credit Suisse	0.0534	Chemical Bank	0.0463
Credit Suisse	0.0589	Societe Generale	0.0448	Credit Suisse	0.0449
Chemical Bank	0.049	Chemical Bank	0.0444	Societe Generale	0.0419
Societe Generale	0.0466	BHF Bank	0.0436	BHF BANK	0.0416
Rabobank Nederland	0.0409	Rabobank Nederland	0.0367	Lloyds Bank	0.0386
Lloyds Bank	0.04	Lloyds Bank	0.0359	Rabobank Nederland	0.0386
Dresdner Bank	0.0265	Amsterdam-Rotterdam	0.0355	Amsterdam-Rotterdam	0.0311
Credit Lyonnais	0.0229	Barclays Bank	0.0268	Citibank	0.0272
Amsterdam-Rotterdam	0.0222	Dresdner Bank	0.0264	Den Danske Bank	0.0237
07/1993		08/1993		09/1993	
Deutsche Bank-Asia	0.0801	Deutsche Bank-Asia	0.0729	Deutsche Bank	0.0733
BHF BANK	0.0662	BHF BANK	0.0572	Banque de l Union	0.0653
Credit Suisse	0.0536	Rabobank Nederland	0.0515	BHF BANK	0.0595
Chemical Bank	0.0411	Credit Suisse	0.0461	Rabobank Nederland	0.0527
Rabobank Nederland	0.0371	Chemical Bank	0.0442	Societe Generale	0.049
Lloyds Bank	0.0353	Lloyds Bank	0.0384	Credit Suisse	0.0475
Credito Italiano	0.0323	Societe Generale	0.0379	Lloyds Bank	0.0433
Amsterdam-Rotterdam	0.0283	Credito Italiano	0.0316	Chemical Bank	0.031
Societe Generale	0.0276	Citibank	0.0266	Dresdner Bank	0.0289
Dresdner Bank	0.0254	Dresdner Bank	0.0236	Den Norske Bank	0.0259
11/1993		12/1993		01/1994	
CFCIC-UE	0.0928	DEUTSCHE Bank	0.1159	CFCIC-UE	0.0923
DEUTSCHE Bank	0.0754	CFCIC-UE	0.087	DEUTSCHE BK	0.077
SOC GENERALE	0.0659	SOC GENERALE	0.0826	RABOBANK	0.0743
BHF Bank	0.0612	Rabobank	0.0747	SOC GENERALE	0.0737
Rabobank	0.051	Barclays	0.0465	Credit Suisse	0.0586
Credit Suisse	0.0389	BHF Bank	0.0344	Barclays	0.0312
Barclays	0.027	Credit Suisse	0.0343	CREDITO	0.0294
Raiffeisen Zentralbank	0.0239	LLOYDS BANK	0.0289	BHF Bank	0.0275
VUW Bank	0.0233	DEN NORSKE	0.0215	LLOYDS BANK	0.0237
Chemical bank	0.0226	UBS	0.0214	UBS	0.0217
02/1994		03/1994		04/1994	
DEUTSCHE BK	0.1211	DEUTSCHE BK	0.1002	CFCIC-UE	0.1336
RABOBANK	0.0739	CFCIC-UE	0.0892	RABOBANK	0.1049
CFCIC-UE	0.0618	SOC GENERALE	0.0753	SOC GENERALE	0.0448
SOC GENERALE	0.0605	RABOBANK	0.0668	DEUTSCHE BK	0.0352
Barclays	0.0385	CREDITO	0.0313	R Z B	0.0344
CREDITO	0.0305	UBS	0.0302	ABN AMRO	0.0309
LLOYDS BANK	0.0292	Barclays	0.0276	Barclays	0.0297
R Z B	0.0247	R Z B	0.0251	CITIBANK	0.027
UBS	0.0232	CITIBANK	0.0239	CREDITO	0.0235
Chemical bank	0.0226	LLOYDS BANK	0.023	BHF Bank	0.0231

Table 6: Information Shares Versus News Arrival

This table reports the regression results of equation $IS_t = \alpha + \beta_1 NA_t + \beta_2 NA_t EBS_t + \eta_t$

Numbers above the parentheses are estimated coefficients and numbers in the parentheses are the corresponding t-statistics. Top 5 dealers every month in terms of the number of quotes given; same definition applies to other top dealers. * indicates the coefficient is significant at 5% significance level.

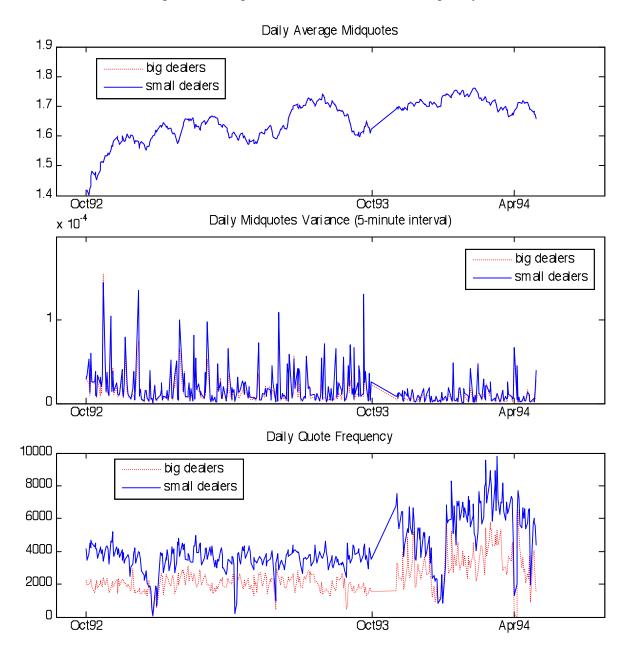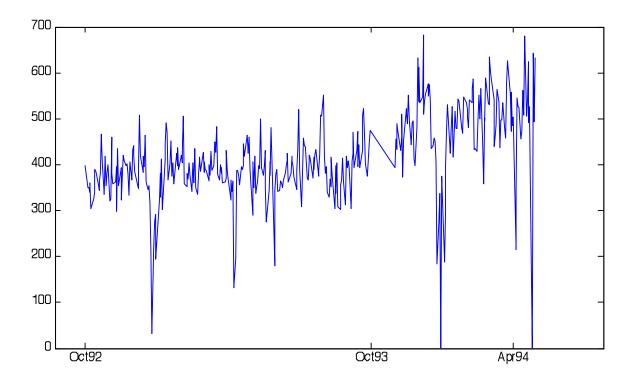|	#obs	Constant	News arrival	News arrival * system dummy	R-squared
Panel A:					
Top 5 dealers	3096	0.5396* (121.00)	0.0014* (7.19)	-0.0016* (-14.66)	0.0652
Top 10 dealers	3096	0.5140* (195.84)	0.0009* (7.91)	-0.0012* (-18.58)	0.1021
Top 20 dealers	3096	0.4761* (136.90)	-0.0010* (-6.94)	0.0020* (23.77)	0.1657
Panel B:					
1.5 hours Window Period (top 5 dealers)	2065	0.5578* (157.79)	0.0005* (4.39)	-0.0011* (-12.56)	0.0736
2 hours Window Period (top 5 dealers)	1549	0.5330* (70.87)	0.0010* (6.39)	-0.0009* (-12.07)	0.1021

Figure 1: Midquote, Variance and Quote Frequency

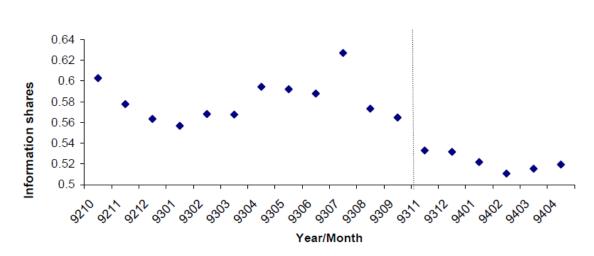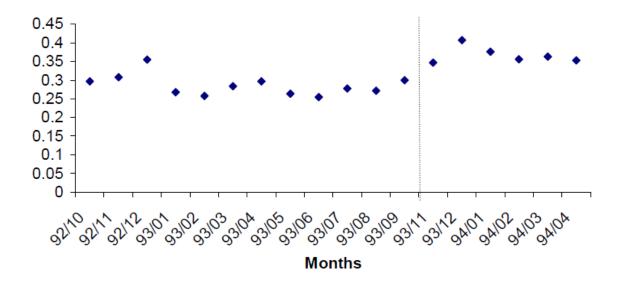Figure 2: Daily News Arrival Frequency

Figure 3: Big Dealers (top 5) Information Shares
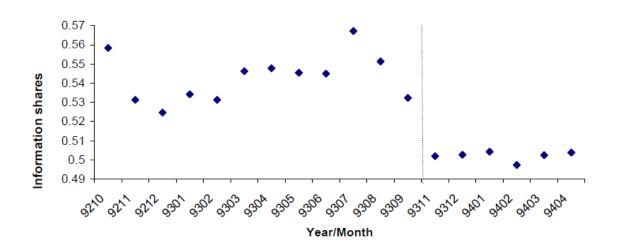(1 Hour After News)

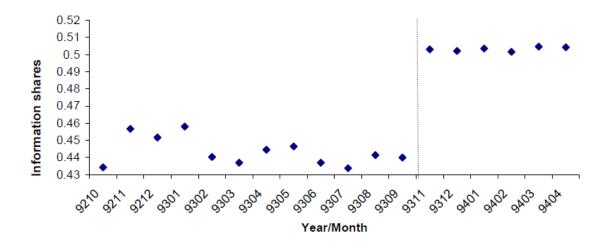

Figure 4: Big Dealers (top 5) Quote Ratios

Figure 5: Big Dealers (top 10) Information Shares
(1 Hour After News)

Figure 6: Big Dealers (top 20) Information Shares
(1 Hour After News)

Figure 7: Big Dealers (top 5) Information Shares
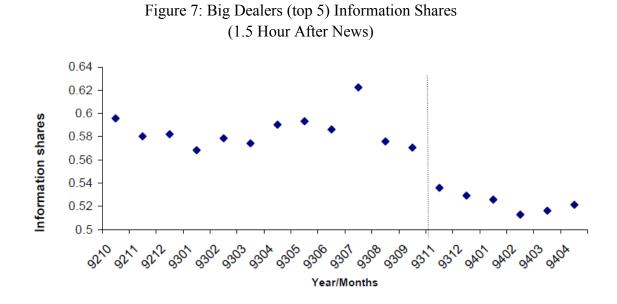(1.5 Hour After News)

Figure 8: Big Dealers (top 5) Information Shares
(2 Hour After News)