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Limit Order, Market Order and Cancellation in Foreign Exchange Market: One Particular Day Experience[1]

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Abstract

In this paper, we try to explore the foreign exchange market microstructure with all transaction records in a day. Our data set, " EBS Market Data ", contains all the transaction in a day. EBS Market Data records all the transaction for 24 hours starting from 22:00:00 in previous day to next day. We apply Autoregressive Conditional Duration model for uneven spaced tick by tick foreign exchange rate. This data set enables us to use limit order data, market order data and exit information of limit order individually. Fact findings are as follows. New York market is the busiest no matter what kind of currencies dealers trade and regardless of the time of the day. Around half of limit orders of three currencies are cancelled. With ACD model, result suggests strong evidence that there exists duration persistency in all data set. Volume has positive and volatility has negative impact. Larger volume order shorten the duration, and higher volatility induce more trades.

Keywords: limit order, market order, cancellation, ACD model, market microstructure

Introduction

Foreign exchange market is one of the largest financial markets in the world. Same financial asset can be traded in different market in different country. If we use a cross listed stock data from a market in a country, this data is different in different country even though the company is same. But foreign exchange rate such as USD/JPY is same in everywhere in the world. To be accurate, this is why we can compare the market features among different countries with same asset if we use foreign exchange rate.

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In this paper, we try to explore the foreign exchange market microstructure with all transaction records in a day. There are many papers that have been devoting to explore the microstructure of foreign exchange market with EBS data[i]. Many of them are using even spaced data[ii]. EBS Data Mine Version 5 provides us four data at most in a second. Our data, " EBS Market Data ", records all the transaction on the trading platform provided by ICAP for 24 hours starting from 22:00:00 in previous day to next day[iii]. This " EBS Market Data " looks like a limit order book. All the limit order, market order and exit information by cancellation or hit by market or limit order are available.

ICAP trading platform is covering wider share of the transactions of particular currency pairs, such as EUR/USD, USD/JPY and EUR/JPY. Thus, we choose EUR/USD, EUR/JPY and USD/JPY, most traded currency pairs in foreign exchange market in this research. As these currencies are most traded in the world, the possibility of arbitrage opportunity must be lowest. Under the arbitrage free condition, we try to compare the results among them and to see what might be happen. We can expect that the microstructure can be similar because of the arbitrage condition.

As our data is real tick by tick and uneven spaced foreign exchange rate data, we cannot apply GARCH type method. Then, we try to use Autoregressive Conditional Duration method proposed by Engle and Russell (1995, 1998). To avoid uneven spaced data problem, we use Log type ACD model[iv] and explore the market microstructure. In the analysis, we use limit

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i See Ito *et al*, (2012) Breedon and Ronaldo (2012).

ii Precisely speaking, even though we use EBS Data Mine ver.5, interval between the data is uneven. There are at most four data in a second. But the interval among four is uneven.

iii For details about the data, see Susai and Yoshida (2014).

iv See more discussion on the ACD type models, Fernandes and Grammig (2006).

order data, market order data and the record of exit from the limit order book individually so that the difference between order types can be revealed.

Rest of this paper is as follows. In the next section, we explain our data in detail. Following the data section, we estimate ACD model and check the results. Finally, we discuss on the market microstructure and conclude the discussion.

Data Description

In this paper, we use "EBS Market Data"[v] on the 8th of September, 2011. Even though we use only one day, 550,693 of EUR/JPY, 371,424 of EUR/USD and 207,752 of USD/JPY data can be used. Most traded foreign exchange rate is EUR/JPY on this day[vi]. EBS Market Data is not the data that ICAP used to provide to us, such as Data Mine Version 1 or Version 5. Even in the Data Mine Version 5, there are four data at most within one second. "EBS Market Data" contains all the transaction record in a day including many pairs of currencies and some commodities. Time spans for 24 hours from 22:00:00 to 21:59:59. In our analysis, we use EUR/USD, EUR/JPY and USD/JPY that are most traded financial assets in the world.

Recorded transactions are quote submitted (QS), quote deleted (QD), market hit submission (HS) and some messages that explain the trade details such as the amount traded, taker and maker information and so on. Each record contains masked submitters' ID and millisecond timestamp. QS and HS have dealers' region indicator, such as New York (NY), London (LN) and Tokyo (TY). QS is a limit order and contains quote price and

v See, "EBS Market Data: Data Format," ICAP, March, 2011.

vi As we checked the economic events on this day, we cannot find any special events. In general, EUR/USD is most traded financial asset.

volume, and bid and offer indicator. HS records market order and has hit price and amount, sell and buy indicator. QD has dealt amount and cancel indicator. Hereafter, we use these three different types of transaction data.

The data we use here is high frequency real traded data. Many papers have been using UHF data from stock market, but it has been hard to use foreign exchange real traded all the transaction records. One of the features of tick by tick UHF is uneven spaced data, time series econometric methods are not suitable to use. For dealing with this difficulty, we construct duration between the orders. Duration is defined as follows.

$$D\_R_t = x_t - x_{t-1} \tag{1}$$

Where D_R_t is duration of each data, and x_t is timestamp of a variable x at time t. In Table 1, we show basic statistics for three currencies.

Basic Statistics

D_R is duration, and D_R30 adds up 30 durations from present to past, D_R 60 is the total sum of 60 past durations. RATE is foreign exchange rate and L_RATE is log difference of RATE. VAR_5 is the standard deviation of five past L_RATEs and VAR_10 is standard deviation for ten past L_RATEs. These VAR variables measure the volatility of foreign exchange rate. VOLUME shows the market order (HS) and limit order (QS) volume. VOLUME_60 is the sum of 60 past volume of each order type.

We can confirm that it takes at least 30 seconds in every currency pairs for 60 transactions. Mean duration is less than one second in three currency pairs and the shortest mean time for 60 transactions is 9 seconds in EUR/JPY. In terms of volatility, USD/JPY is the highest and EUR/JPY is the

Table **1.** Basic Statistics

EUR/USD

	D_R	D_R 30	D_R 60	L_RATE	RATE	VAR_5	VAR_10	VOLUME	VOLUME_60
Mean	0:00:00	0:00:07	0:00:14	−0.002%	1.271332	0.000011%	0.000017%	1281891	39771574
Maximum	0:06:05	0:16:51	0:30:40	0.55%	1.2904	0.000516%	0.000216%	1.50E+08	2.86E+08
Minimum	0:00:00	0:00:00	0:00:00	−1.25%	1.2603	0.00%	0.00%	1000000	0
Sum	23:59:40	19:23:06	10:01:59					2.50E+11	1.48E+13
Observations	371424	371395	371365	100628	195320	9009	977	195320	371367

USD/JPY

	D_R	D_R 30	D_R 60	L_RATE	RATE	VAR_5	VAR_10	VOLUME	VOLUME_60
Mean	0:00:00	0:00:12	0:00:25	−0.0020%	83.77657	0.00005%	0.00003%	1255142	38610424
Maximum	0:06:46	0:23:03	0:33:29	8.82%	91.31	0.130%	0.00092%	2.50E+08	2.82E+08
Minimum	0:00:00	0:00:00	0:00:00	−5.71%	80	0.00%	0.00%	1000000	1000000
Sum	23:56:42	17:30:14	2:27:14					1.36E+11	8.02E+12
Observations	207752	207723	207693	54735	108320	4753	473	108320	207695

EUR/JPY

	D_R	D_R 30	D_R 60	L_RATE	RATE	VAR_5	VAR_10	VOLUME	VOLUME_60
Mean	0:00:00	0:00:05	0:00:09	−0.00035%	106.5314	0.0000090%	0.0000049%	1157091	34841376
Maximum	0:02:53	0:09:21	0:11:15	2.57%	108.9	0.00302%	0.00007%	1.00E+08	2.37E+08
Minimum	0:00:00	0:00:00	0:00:00	−1.88%	103.65	0.00%	0.00%	1000000	10000000
Sum	23:59:51	22:16:25	17:04:09					3.25E+11	1.92E+13
Observations	550693	550664	550634	139180	281054	10279	769	281054	550636

Table 2. Mean Value of each Variables of EUR/USD, EUR/JPY and USD/JPY

[All Data]

	D_R	D_R 30	D_R 60	VOLUME	VOLUME_60	NY	London	Tokyo
EUR/USD	0:00:00	0:00:07	0:00:14	1281891	39771574	50.5%	40.7%	8.8%
EUR/JPY	0:00:00	0:00:05	0:00:09	1167096	35096535	58.7%	31.5%	9.9%
USD/JPY	0:00:00	0:00:12	0:00:25	1255142	38610424	51.9%	28.9%	19.2%

[QD]

	D_R	D_R 30	D_R 60	VOLUME	VOLUME60	Bid	Offer	Canlelled
EUR/USD	0:00:00	0:00:15	0:00:29	156135.01	9366281.35	26.0%	26.5%	47.6%
EUR/JPY	0:00:00	0:00:10	0:00:19	48220.03	2893841.88	25.7%	25.1%	49.2%
USD/JPY	0:00:01	0:00:26	0:00:51	121901.18	7310805.64	25.3%	26.7%	48.1%

[QS]

	D_R	D_R 30	D_R 60	RATE	L_RATE	VAR_5	VAR_10	VOLUME	VOLUME60	NY	London	Tokyo
EUR/USD	0:00:00	0:00:11	0:00:23	1.27	0.000000%	0.000019%	0.000020%	1286119.0	77336443.9	49.0%	50.8%	0.2%
EUR/JPY	0:00:00	0:00:02	0:00:04	106.26	−0.000226%	0.000010%	0.000010%	1050949.1	62998002.0	48.4%	48.4%	3.3%
USD/JPY	0:00:01	0:00:25	0:00:50	83.78	0.000000%	0.000082%	0.000085%	1197681.6	71848526.4	51.7%	28.3%	20.0%

[HS]

	D_R	D_R 30	D_R 60	RATE	L_RATE	VAR_5	VAR_10	VOLUME	VOLUME60	NY	London	Tokyo
EUR/USD	0:00:05	0:02:18	0:04:29	1.271	−0.0000174%	0.0000006%	0.0000006%	1743306.7	104573205.4	50.7%	46.3%	3.0%
EUR/JPY	0:00:07	0:03:33	0:06:54	106.47	−0.0000419%	0.0000009%	0.0000010%	1427295.8	85424146.4	50.3%	41.6%	8.1%
USD/JPY	0:00:34	0:21:11	0:47:57	83.79	−0.0007112%	0.0000565%	0.0000582%	2092715.2	130457142.9	49.7%	31.8%	18.5%

lowest. This is consistent that highest USD/JPY rate is 91.31 and lowest rate is 80, then the rate of change is 14% (3323% per year) whereas it is 5 % for EUR/JPY. Even though the trading volume, in other word trading activity, of EUR/JPY is the highest, volatility is the lowest. Based on earlier researches, volatility increases with heavier trading activity. Higher trading volume with lower volatility is implying that dealers do not want to cause the price change when they trade. If liquidity dealer wants to deal a large amount without any impact on the price, they used to split their order into smaller volume order. This kind of splitting order strategy tends to induce larger volume with lower volatility.

Table 2 shows QD, QS and HS basic statistics individually. In terms of the duration, QS is the shortest and HS is the longest. From the all data statistics, New York market is the largest in all three currencies. Tokyo market is only bigger in USD/JPY trade, but not so big in EUR/JPY. Then, we might say that EUR is cross currency in Tokyo market. This tendency is almost same in QS and HS statistics.

From QD data, around half of the transactions are cancellation. As QD records the exit of limit orders from market, we can confirm that around half of the reason for the exit of limit orders in foreign exchange market is cancellation[vii]. The portion of bid and offer transaction is almost same.

In terms of the duration for 60 transactions in all statistics, EUR/JPY is the shortest and USD/JPY is the longest in QD and QS, but EUR/USD is the shortest in HS. Among QD, QS and HS, limit order QS is the shortest and market order HS is the longest. From the volatility point of view, market order HS is relatively lower, and comes with shorter duration and larger

vii This rate is relatively high. Cancellation rates are reported in many papers as follows; 20% in Paris Bourse (Biais *et al*. (1995)), 56% in NYSE (Harris and Hasbrouck (1996)), 40% in NYSE (Yeo (2005)).

volume.

With all the facts we already discussed so far, limit order QS shows shorter duration and higher volatility, but smaller volume. From the theoretical research, higher volatility comes with heavier trading activity, larger volume[viii]. But in this statistics, we find that limit order tends to be more trades with smaller volume, but price dispersion is wider. This is consistent that if limit order dealers are mainly liquidity dealers and they want to reduce free option risk, then they might split their orders into smaller volume orders[ix]. Splitting order strategy used to aim at not affecting the price. But in our statistics, price volatility is higher in limit order trading. The order at farer from the best bid and offer price with smaller volume means lower execution risk, but lower free option risk. If limit order dealer put larger importance on avoiding free option risk, we can say that large part of limit dealers are liquidity dealers. On the other hand, market order dealers trade larger volume with limited opportunity (narrower price dispersion). If market dealers have some information on the asset price, then they can buy or sell larger volume at the price based on their information.

From Table 3 to 6, we decompose all the data into four time zones, Tokyo, London, London and New York, and New York. As we can use dealers region, here we want to pay special attention on the trading time.

In all time zone, EUR/JPY durations for 60 trades are the shortest and volatilities in 10 trades are the lowest. Even if we divide all the data into major time zones, the tendency is same. During Tokyo time, trades of three

viii Mixture of Distribution Hypothesis is one of most popular discussions.

ix If limit order is large and limit order dealer is liquidity dealer, then this large order gives opportunity to gain by informed dealer. Many researchers are defining this opportunity for informed dealers as free option and as free option risk for liquidity dealers (Fong and Liu (2010)).

Table **3.** Mean Value in Tokyo time zone

	D_R	D_R 60	VAR_5	VAR_10	VOLUME	NY market	London market	Tokyo market
EUR/USD	0:00:00	0:00:26	0.0000090%	0.0000050%	1259907	29.40%	35.50%	35.20%
EUR/JPY	0:00:00	0:00:20	0.0000120%	0.0000043%	1113625.4	36.40%	26.10%	37.50%
USD/JPY	0:00:01	0:00:35	0.0000224%	0.0000217%	1232392.3	23.80%	20.10%	56.10%

	BID ID	OFFER ID	BUY ID	SELL ID	QS ID	QD ID	HS ID
EUR/USD	42845	43145	1659	1574	42990	43000	3233
EUR/JPY	59724	7116	1497	1719	58742	58687	3216
USD/JPY	31735	32235	1163	1153	32044	31926	2316

Table **4.** Mean Value in London time zone

	D R	D R 60	VAR 5	VAR 10	VOLUME	NY market	London market	Tokyo market
EUR/USD	0:00:00	0:00:11	0.0000093%	0.0000097%	1298894.1	37.90%	60.90%	1.20%
EUR/JPY	0:00:00	0:00:07	0.0000071%	0.0000067%	1100966.7	50.30%	45.00%	4.70%
USD/JPY	0:00:00	0:00:21	0.0001320%	0.0000306%	1295896.7	36.70%	58.60%	4.60%

	BID ID	OFFER ID	BUY ID	SELL ID	QS ID	QD ID	HS ID
EUR/USD	38652	39411	1989	2085	39239	38824	4074
EUR/JPY	62921	63099	1735	1557	63017	63002	3292
USD/JPY	19110	20220	962	994	19734	19596	1956

Table **5.** Mean Value in London and NY time zone

	D_R	D_R 60	VAR_5	VAR_10	VOLUME	NY market	London market	Tokyo market
EUR/USD	0:00:00	0:00:25	0.0000101%	0.0000079%	1292357.8	83.70%	16.10%	0.20%
EUR/JPY	0:00:00	0:00:13	0.0000059%	0.0000058%	1176306.7	77.20%	22.40%	0.30%
USD/JPY	0:00:01	0:00:39	0.0000390%	0.0000365%	1215701.7	89.30%	9.90%	0.80%

	BID_ID	OFFER_ID	BUY_ID	SELL_ID	QS_ID	QD_ID	HS_ID
EUR/USD	20149	20616	919	812	20396	20369	1731
EUR/JPY	43057	41007	576	529	6551	42084	135
USD/JPY	12953	13100	438	556	12979	13074	994

Table **6.** Mean Value in NY time zone

	D_R	D_R 60	VAR_5	VAR_10	VOLUME	NY market	London market	Tokyo market
EUR/USD	0:00:00	0:00:25	0.0000101%	0.0000079%	1292357.8	83.70%	16.10%	0.20%
EUR/JPY	0:00:00	0:00:13	0.0000059%	0.0000058%	1176306.7	77.20%	22.40%	0.30%
USD/JPY	0:00:01	0:00:39	0.0000390%	0.0000365%	1215701.7	89.30%	9.90%	0.80%

	BID_ID	OFFER_ID	BUY_ID	SELL_ID	QS_ID	QD_ID	HS_ID
EUR/USD	20149	20616	919	812	20396	20369	1731
EUR/JPY	43057	41007	576	529	6551	42084	135
USD/JPY	12953	13100	438	556	12979	13074	994

currencies are higher in Tokyo region, EUR/USD is exceptional and is most traded in London Region. In London time, EUR/USD and USD/JPY are most traded in London region but EUR/JPY is most in New York region. This time zone is early in the morning in New York. Even early in the morning, many orders of EUR/JPY are from New York region. In London and New York and New York time zone, more than 60 percent of orders are from New York region.

Empirical Model

Autoregressive Conditional Duration model

Following Engle and Russell (1995, 1998), we derive ACD model as follows. With the duration (D_R_t(for simplicity, D_t)) and each event time stamp (x_t), we can construct the conditional expected value of duration as below.

$$E(D_t|D_{t-1},D_{t-2},\cdots D_1)=\gamma_t(D_{t-1},D_{t-2},\cdots D_1;\theta)\equiv\gamma_t \tag{2}$$

Then we assume,

$$D_t=\gamma_t\varepsilon_t \tag{3}$$
$$\{\varepsilon_t\}\sim i.i.d.$$

This assumption allows us to describe the duration as mean function of γ_t. In this paper, we adopt Log ACD model.

$$\ln(\gamma_t)=c+\sum_{i=1}^{m}\alpha_i D_{t-1}+\sum_{j=1}^{n}\beta_i\gamma_{t-1}+\sum_{k=1}^{o}\rho_k z_k \tag{4}$$

z_ks are exogenous variables. From (3) to (4), we can derive the quasi-likelihood function.

$$\ln(L)=-\sum_{i=1}^{N}\ln(\gamma_t)+\frac{D_i}{\gamma_i} \tag{5}$$

Estimation model

Figure 1 to 13 in the appendix are the duration of each variable. Because the shape of all figures looks similar and shows some seasonality, we deal with this seasonality as below.

To get the smoothing series (η_t) for solving the seasonality matters, we use exponential smoothing with Hold-Winters additive seasonal variation method. Hereafter, we use seasonality adjusted duration in all estimations.

$$\hat{\gamma}_t = \frac{\gamma_t}{\eta_t} \tag{6}$$

We incorporate volume variables, volatility variables, trade indicators and market indicators into the model as z_k. Not only the total volume but also buy and sell volume, bid and offer volume are incorporated. We use only volatility for 60 trades as volatility variable. Market indicators of Tokyo, London and New York are also used in the model.

Among several lags in (4), we select most simple model.

$$ln(\hat{\gamma}_t) = c + \alpha D_{t-1} + \beta \hat{\gamma}_{t-1} + \rho_t z_t \tag{7}$$

and $c \geqq 0$, $\alpha, \beta > 0$.

Estimation Results

Table 7 shows base result with all data (including QD, QS and HS) in each currency pair without exogenous variables. Models are estimated significantly and consistent for the parameter constraint. As already mentioned by many papers on the persistency of lagged term, $\alpha+\beta$ can tell us the magnitude of this tendency. Largest value of $\alpha+\beta$ is almost 1.16 in USD/JPY

and around 1 in EUR/USD. Although EUR/JPY shows $\alpha+\beta$ as small as 0.25, all the result shows lagged duration has positive impact on future duration and positive duration clustering exixts. This tendency is strong for EUR/USD and USD/JPY.

Table 7. ACD Model estimation result: All data

	EUR/USD	USD/JPY	EUR/JPY
c	0.154	0.452	0.067
(SE)	0.0003	0.0004	0.001
α	0.480	0.824	0.014
(SE)	0.001	0.001	0.0002
β	0.525	0.347	0.249
(SE)	0.0004	0.0005	0.009
L. Likelihood	−533008.8	−242952	−898036.1

All parameters are estimated significantly at 1%
(SE) shows standard error

Table 8. ACD Model with HS; EUR/USD

	EQ1	EQ2	EQ3	EQ4	EQ5
c	2.2.E−05	0.275	0.941	1.137	1.734
(SE)	5.9.E−08	0.053	0.002	0.018	0.273
α	0.928	0.107	6.7.E−04	5.7.E−04	5.9.E−04
(SE)	0.004	0.017	1.3.E−05	1.2.E−05	1.2.E−05
β	0.094	0.689	0.242	0.354	−0.002*
(SE)	4.2.E−04	0.050	0.001	0.010	0.158
volume		−1E−08			
(SE)		3.75E−09			
buy volume			4.39E−07		
(SE)			9.51E−10		
sell volume				−2.9E−08	
(SE)				4.3E−10	
volatility					−5.6.E+05
(SE)					1.3.E+05
L. Likelihood	160737.3	−941.22	−26688.8	−27253.2	−27292.6

Most parameters except one are estimated significantly at 1%
(SE) shows standard error
*:not significant at 10%

Table **9.** ACD Model with HS; EUR/JPY

	EQ1	EQ2	EQ3	EQ4	EQ5
c	0.965	1.046	1.017	1.083	0.890
(SE)	0.119	0.029	0.063	0.078	0.234
α	0.012	0.011	0.012	0.013	0.015*
(SE)	0.002	0.002	0.002	0.002	0.019
β	0.192	−0.02*	0.119	0.07*	0.483
(SE)	0.099	0.023	0.053	0.065	0.136
volume		1.3.E−07			
(SE)		6.2.E−09			
buy volume			5.3.E−08		
(SE)			4.2.E−09		
sell volume				4.2.E−08	
(SE)				4.6.E−09	
volatility					−5.1.E+07
(SE)					1.E+07
L. Likelihood	−13598.1	−13557.4	−13587.1	−13591	−27820.22

Most parameters except are estimated significantly at 1%
(SE) shows standard error
*:not significant at 10%

Table **10.** ACD Model with HS; USD/JPY

	EQ1	EQ2	EQ3	EQ4	EQ5
c	1.243	1.176	0.528	0.430	0.966
(SE)	0.016	0.014	0.023	0.018	0.119
α	0.075	0.077	0.227	0.232	0.012
(SE)	0.002	0.002	0.017	0.016	0.002
β	0.002*	0.002*	0.331	0.358	0.191**
(SE)	0.012	0.009	0.022	0.019	0.099
volume		3.4.E−08			
(SE)		3.9.E−09			
buy volume			2.5** E−08		
(SE)			1.4.E−08		
sell volume				7.7.E−08	
(SE)				1.2.E−08	
volatility					1.9.E−01
(SE)					1.7.E+05
L. Likelihood	−10688.8	−10676	−897.068	−880.125	−13599.19

All parameters are estimated significantly at 1%
(SE) shows standard error
*:not significant at 10%
**:not significant at 5%

Table 8 to 10 show the result of HS (market order) data. EQ1 is base model that contains no exogenous variables. In Table 8, $\alpha+\beta$ of EQ1 is about 1 and about same for the base result (Table 7). EQ2 and EQ5 in Table 8 show that larger volume and higher volatility reduce the duration, hasten the market hit to limit order. Taking a closer look at the volume, we divide the whole volume into buy and sell volume. Buying market order prolongs the duration, then reduces the market activity. Selling market order shortens the duration and increases the market activity. Selling EUR against USD order hastens the market order.

HS of EUR/JPY shows lower $\alpha+\beta$ value compare to the base result. Con-

Table **11.** ACD Model with QS; EUR/USD

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6	EQ7
c	0.809	0.719	0.826	0.794	0.793	0.788	0.729
(SE)	0.006	0.008	0.010	0.006	0.007	0.007	0.006
α	0.185	0.181	0.184	0.193	0.180	0.182	0.166
(SE)	0.003	0.003	0.003	0.003	0.003	0.003	0.003
β	0.225	0.211	0.228	0.191	0.231	0.208	0.241
(SE)	0.006	0.006	0.006	0.005	0.006	0.006	0.005
volume		9.47E−08					
(SE)		4.76E−09					
volume 60			−3.06E−10				
(SE)			1.2E−10				
bid volume				9.04E−08			
(SE)				2.8E−09			
offer volume					1.78E−08		
(SE)					1.86E−09		
NY							−0.078
(SE)							0.004
LN							0.409
(SE)							0.009
TY							
(SE)							
volatility						220373.5	282917.2
(SE)						10899.9	11390.2
L. Likelihood	−21171	−21111.2	−21054.37	−21136.45	−21165.9	−21115.29	−21037.84

All parameters are estimated significantly at 1%

(SE) shows standard error

trary to the EUR/USD result, volume has positive impact on duration (reduce the trading activity). This is partly from the impact of selling volume on the duration. Selling EUR against JPY also discourages the market order.

Market order result of USD/JPY is much different from the result of base case. $\alpha+\beta$ value of EQ1 in Table 10 is 0.075. Not only volume but also volatility has positive impact on the duration. All the exogenous variable are positively estimated.

Limit order of EUR/USD shows different tendency on the persistency of the past duration. The value of $\alpha+\beta$ in Table 11 is much smaller than that of

Table **12.** ACD Model with QS; EUR/JPY

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6	EQ7
c	0.407	0.317	0.468	0.387	0.400	0.407	0.436
(SE)	0.001	0.002	0.002	0.001	0.001	0.001	0.001
α	0.403	0.401	0.403	0.402	0.403	0.403	0.413
(SE)	0.002	0.002	0.002	0.002	0.002	0.002	0.002
β	0.320	0.316	0.320	0.318	0.320	0.320	0.309
(SE)	0.001	0.001	0.001	0.001	0.001	0.001	0.001
volume		8.4E-08					
(SE)		1.83E-09					
volume 60			-8.9E-10				
(SE)			2.62E-11				
bid volume				3.98E-08			
(SE)				9.59E-10			
offer volume					1.33E-08		
(SE)					8.73E-10		
NY							
(SE)							
LN							-0.097
(SE)							0.001
TY							0.087
(SE)							0.002
volatility						-1155.9	
(SE)						360.2	
L. Likelihood	-281292	-280823	-281172	-281054	-281266	-281265	-280565.4

All parameters are estimated significantly at 1%

(SE) shows standard error

base case. All the exogenous variables except New York indicator have positive sign. Larger volume and higher volatility come with longer duration. Relative to other market, duration might be shorter in New York.

Result from EUR/JPY limit order data shows stronger persistency compare to the base case. $\alpha+\beta$ is more than 0.7 and more than triple of the base result. Past volume and volatility shorten the duration, but other variables have positive impact on the duration.

Table **13.** ACD Model with QS; USD/JPY

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6	EQ7
c	0.790	0.595	1.135	0.739	0.776	0.255	0.746
(SE)	0.002	0.002	0.002	0.002	0.002	0.017	0.002
α	0.384	0.385	0.384	0.388	0.383	0.278	0.379
(SE)	0.002	0.002	0.002	0.002	0.002	0.016	0.002
β	0.138	0.133	0.149	0.137	0.138	0.613	0.163
(SE)	0.001	0.001	0.001	0.001	0.001	0.020	0.001
volume		1.71E-07					
(SE)		1.86E-09					
volume 60			-5.00E-09				
(SE)			2.26E-11				
bid volume				8.86E-08			
(SE)				1.01E-09			
offer volume					2.35E-08		
(SE)					9.28E-10		
NY							-0.037
(SE)							0.001
LN							
(SE)							
TY							0.171
(SE)							0.002
volatility						-2342.31	
(SE)						19.832	
L. Likelihood	-115929.3	-115425.6	-115502	-115658	-119387	-115893	-115620

All parameters are estimated significantly at 1%

(SE) shows standard error

Although the relative persistency of EUR/JPY case is lower, the impact of exogenous variables is same. Higher past volume and volatility have nega-

Table **14.** ACD Model with QD; EUR/USD

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6
c	0.718	0.685	0.759	4.104	0.442	0.428
(SE)	0.001	0.001	0.001	0.010	0.001	0.001
α	0.412	0.415	0.414	0.355	0.309	0.307
(SE)	0.001	0.001	0.001	0.001	0.001	0.001
β	0.204	0.200	0.201	0.361	0.354	0.365
(SE)	0.001	0.001	0.001	0.001	0.001	0.001
bid id		0.074				
(SE)		0.001				
offer id			−0.074			
(SE)			0.001			
cancell id				−3.804		
(SE)				0.010		
bid volume					3.1.E−06	
(SE)					1.2.E−08	
offer volume						3.1.E−06
(SE)						1.3.E−08
L. Likelihood	−209394	−209295	−209295	−179378	−196971	−196522

All parameters are estimated significantly at 1%
(SE) shows standard error

Table **15.** ACD Model with QD; EUR/JPY

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6
c	0.454	0.431	0.476	0.269	0.232	0.529
(SE)	0.001	0.001	0.001	0.002	0.008	0.011
α	0.437	0.437	0.437	0.431	0.175	0.204
(SE)	0.001	0.001	0.001	0.001	0.005	0.005
β	0.284	0.284	0.284	0.293	0.637	0.348
(SE)	0.001	0.001	0.001	0.001	0.009	0.011
bid id		0.045				
(SE)		0.001				
offer id			−0.045			
(SE)			0.001			
cancell id				0.183		
(SE)				0.002		
bid volume					−9.0E−08	
(SE)					1.49E−08	
offer volume						−5.6E−08
(SE)						1.64E−08
L. Likelihood	−290676	−290582	−290582	−290445	−294914	−294133

All parameters are estimated significantly at 1%
(SE) shows standard error

Table **16.** ACD Model with QD; USD/JPY

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6
c	0.009	0.956	1.051	4.093	0.701	0.692
(SE)	0.0001	0.002	0.002	0.017	0.002	0.002
α	−0.002	0.369	0.369	0.253	0.224	0.226
(SE)	3.5.E-06	0.002	0.002	0.001	0.001	0.001
β	0.995	0.104	0.104	0.342	0.306	0.311
(SE)	0.000	0.001	0.001	0.001	0.001	0.001
bid id		0.096				
(SE)		0.001				
offer id			−0.096			
(SE)			0.001			
cancell id				−3.57		
(SE)				0.02		
bid volume					2.63E−06	
(SE)					1.54E−08	
offer volume						2.58E−06
(SE)						1.48E−08
L. Likelihood	−135075	−132177	−132177	−124776	−131000	−131344

All parameters are estimated significantly at 1%
(SE) shows standard error

tive impact on the duration. These mean that aggressive limit order or higher volatility induce active limit orders.

The result of QD is difficult to induce clear implication. QD is showing exit transaction from the market, and there are some reasons to decide to exit. We can surely say that there exists duration persistency even in the exit transaction. So, when the exit transaction increase, for example cancellation, more exits will be induced. Exit transaction shows also transaction clustering.

Discussion

There are many debates on the behavior of individual dealers (or traders) in foreign exchange market theoretically and empirically. Because dealer based data in foreign exchange market has not been available for many

years, empirical research has been facing some difficulties. Foreign exchange market is not a centralized market and more like OTC market without central governing organization. In this paper, we try to examine the dealers' behavior with special data set provided by ICAP.

As we mentioned earlier, we especially focus on limit order and market order data set[x]. Engle and Russel (1998) analyzed trader's behavior with stock data. They incorporate price variables and volume as exogenous variables. In this paper, as we cannot use bid-ask spread, we try to explore the effect of volume and market activity on the duration. Time span for 60 trades is introduced as market activity indicator[xi] and we incorporate the reciprocal of this indicator as market activity proxy. We call this variable as CALM. If CARM increases, market activity is getting active, in other word, more trades within given time.

Overviewing the results of HS and QS, volume parameters have positive sign in two of HS and all of QS results. In all cases, $\alpha+\beta$ does not change so much. Wider duration means slower trading pace, then lower trading activity. Bigger volume might be generated by new information on the asset, uninformed dealer may avoid to trade against informed dealer. In this case, trading activity has some impact on future trading impact. This is consistent with Easley and O'Hara (1992) discussion[xii].

Also it might be said that this fact is consistent with the behavior of avoiding free option risk. The bigger the trading volume is, the bigger the free option risk becomes. So, when liquidity dealer faces the bigger trading volume, he or she might stop ordering and wait next opportunity.

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x Limited research has been done for analyzing cancellation behavior. See Susai and Yoshida (2015) on the research on foreign exchange market.

xi See Susai and Yoshida (2015).

xii See Easley and O'Hara (1992).

As for the impact of volatility on the duartion, parameters of volatility is negative in two of HS and QS cases. When volatility goes up, trading activity becomes higher. Limit order literatures sugget that volatility may decrease non-execution risk. Following this discussion, we may point out that more liquidity dealers submit orders during high volatility period.

Table **17**. Effect of the Market Activity on the Order Behavior

		EUR/USD		EUR/JPY		USD/JPY	
		OLS	GMM	OLS	GMM	OLS	GMM
HS	α	−1.3E−09	−1.7E−07	−5.3E−08	−3.4E−07	1.3E−02	1.2E−02
	(se)	2.8E−10	3.4E−08	4.3E−09	4.9E−08	4.9E−04	1.7E−03
	β	3.3E−12	1.1E−11****	1.3E−11	1.3E−11****	2..7E−12**	4.8E−12****
	(se)	7.9E−13	9.8E−12	2.5E−12	2.1E−11	1.1E−12	1.5E−11
QS	α	−1.6E−09	−1.7E−07	−2.0E−10	−1.2E−09	−1.0E−10	−2.3E−09
	(se)	2.1E−10	5.9E−09	2.9E−12	1.5E−10	7.9E−12	3.3E−10
	β	7.9E−13****	3.0E−11****	3.3E−13	2.1E−11	6.6E−13	1.1E−11
	(se)	5.4E−13	3.2E−11	2.4E−14	7.4E−12	1.3E−13	7.5E−12
QD	α	−2.3E−11	−2.0E−09	−1.4E−10	−2.0E−09	−3.3E−11	−2.5E−09
	(se)	2.2E−12	4.9E−10	2.5E−12	4.9E−10	4.1E−12	5.7E−10
	β	7.7E−13	5.6E−11	−1.4E−13***	3.5E−12**	8.0E−13	7.9E−11
	(se)	1.0E−13	7.5E−12	7.6E−14	1.5E−12	2.1E−13	1.5E−11

**** not significant at least 10% level
*** significant at 10%
** significant at 5%
All other parameters are significant at 1%

For further discussion, we use CALM and check the impact of CALM on the duration. Independent variable is duration and dependent variables are CALM (α) and volume (β). The purpose of this analysis is to know the relation between market activity and duration. For estimating the model, we use not olny OLS but also GMM.

Almost all parameters of CALM are estimated significantly negative regardless of estimation medthod. This means that lower activity comes with longer duration. In other word, the more active the market becomes, the more number of order dealers submitte.

The parameters of volume are positively estimated. But, not all parameters are significant and especially some parameters that are estimated by GMM are not significant. This results are almost same as the result we get from ACD estimation.

Summary

With tick by tick limit and market order data, we try to explore the dealers submission behavior in foreign exchange market. In our analysis, we are paying special attention on the time span between the transactions. To date, some reseachers has started to use this kind of real trade foreign exchange data, but only a few researchers including us are using limit orer and market order data. One of the method we used to apply when we use tick by tick data is to convert all the data into even speced data. In our analysis, we use all the data and apply ACD model.

One of the advantages of our data is that we can distinguish the limit order, market order and canlellation record. We choose three most traded finanical assets, EUR/USD. EUR/JPY and USD/JPY and construct three data sets, QS as limit order data set, HS as market order data set and QD as cancellation and exit from the market.

Closer looking at the data, we find that New York market is the busiest in all foreign exchange retes and regardless of the time of the day. Around half of the limit orders of three currencies are cancelled. This cancellation rate is relatively high.

Duration analysis gives us some implication on trading features in foreign exchange market. With ACD model, result suggests strong evidence that there exists duration persistency in all data set. This means that trading

clustering exists and foreign exchange market might not follow EMH. Volume and volatility have significant impact on duration. Although there are some exceptions, almost the sign of all parameters are same, and volume has positive and volatility has negative impact on the duration.

Large volume order shorten the duration, and higher volatility induce more trades. If large volume order comes from informed dealer, liquidity dealers may wait for next opportunity. When the market is volatile, price moves a lot and execution probability is higher, then liquidity dealers submit more orders or more liquidity dealers begin to trade.

Though we get significant results from ACD models, we need to explore more in detail on the behavioral features of individual dealers. The interview to the specialist who has been working for one of the Japanse major banks told us that confidence on the market is important and the tendency of the price movement can be changed when confidence in the market changes. We should explore what he feels in his more than 20 years experience in the market.

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Appendix

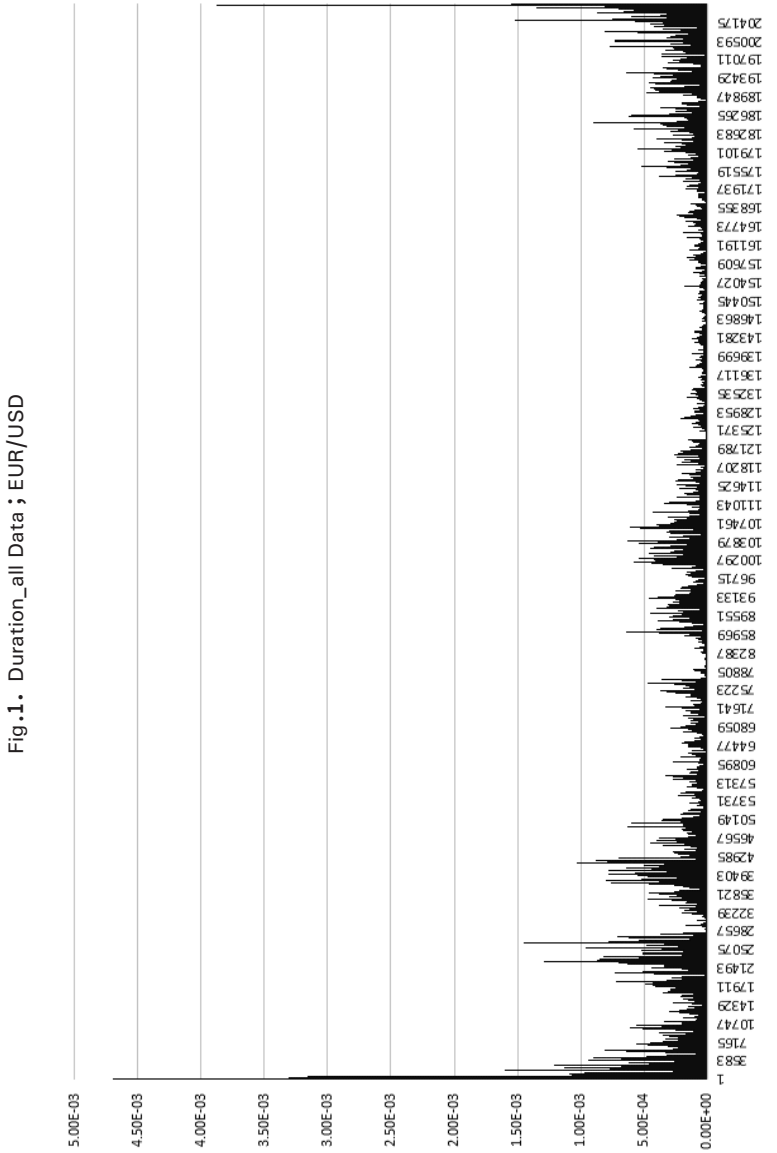

Fig.1. Duration_all Data ; EUR/USD

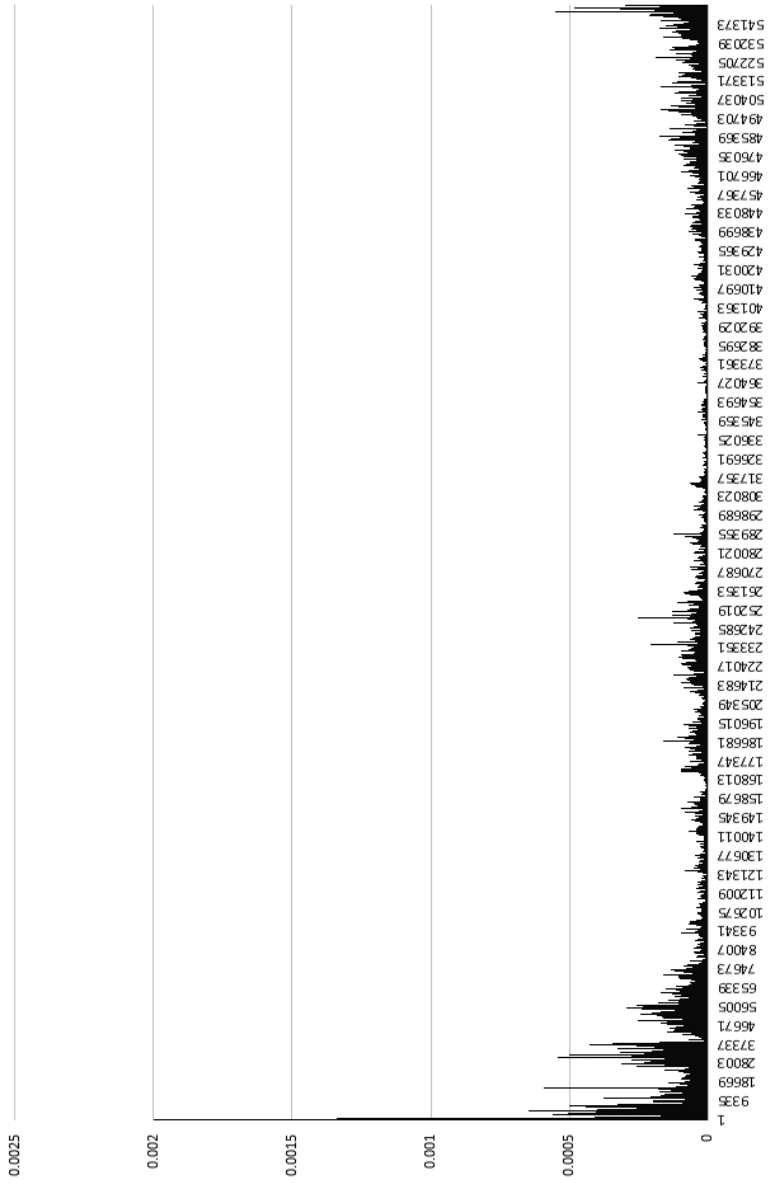

Fig.2. Duration_all Data ; EUR/JPY

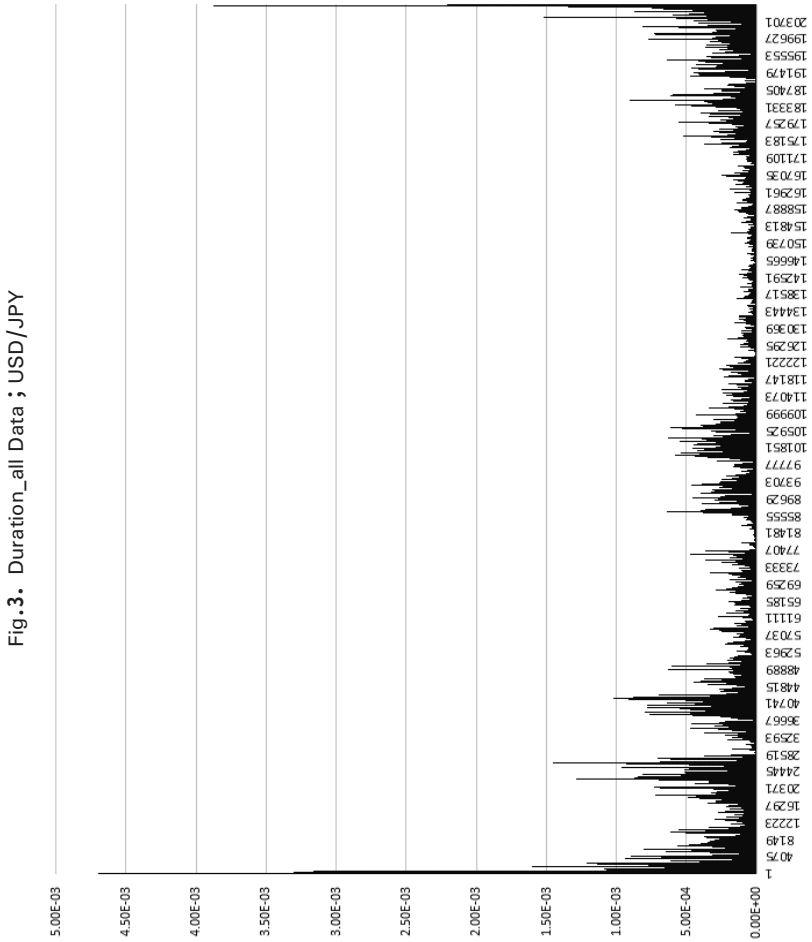

Fig.3. Duration_all Data ; USD/JPY

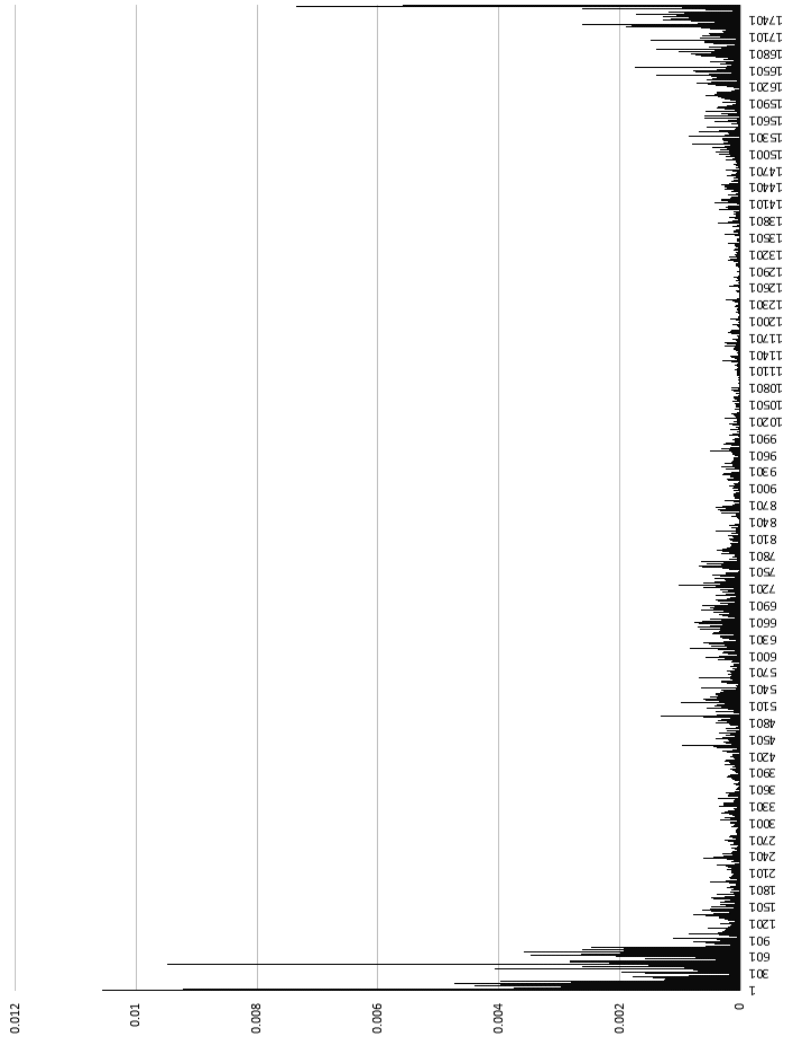

Fig.**4.** Duration_HS；EUR/USD

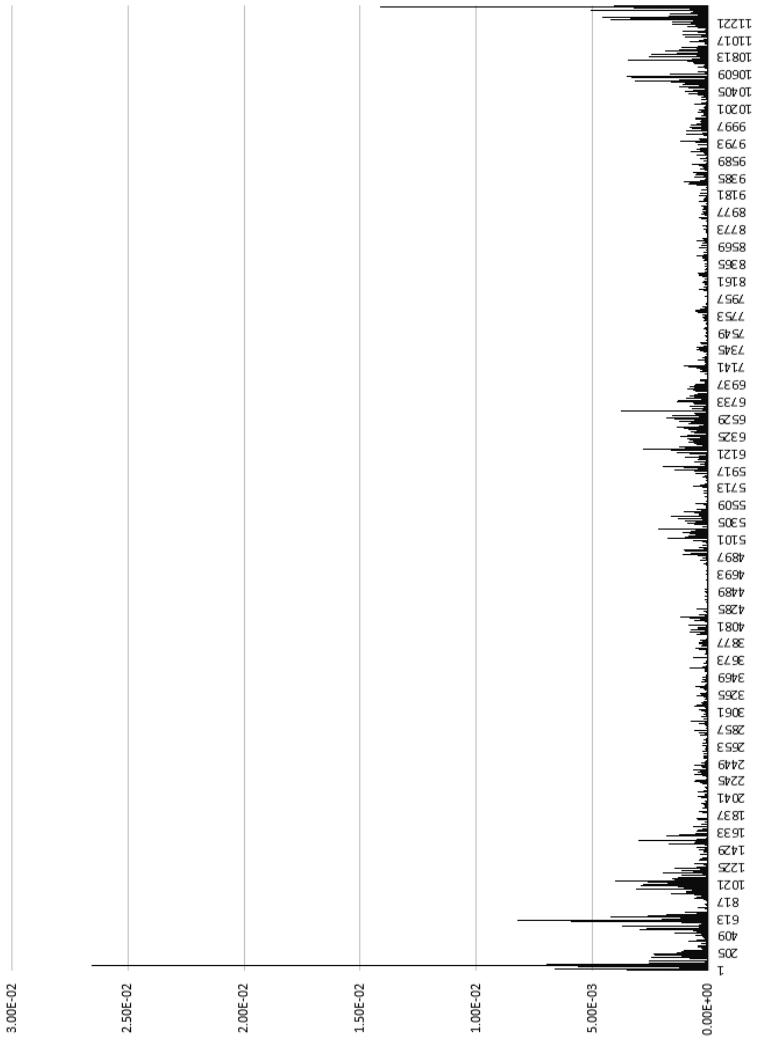

Fig.5. Duration_HS ; EUR/JPY

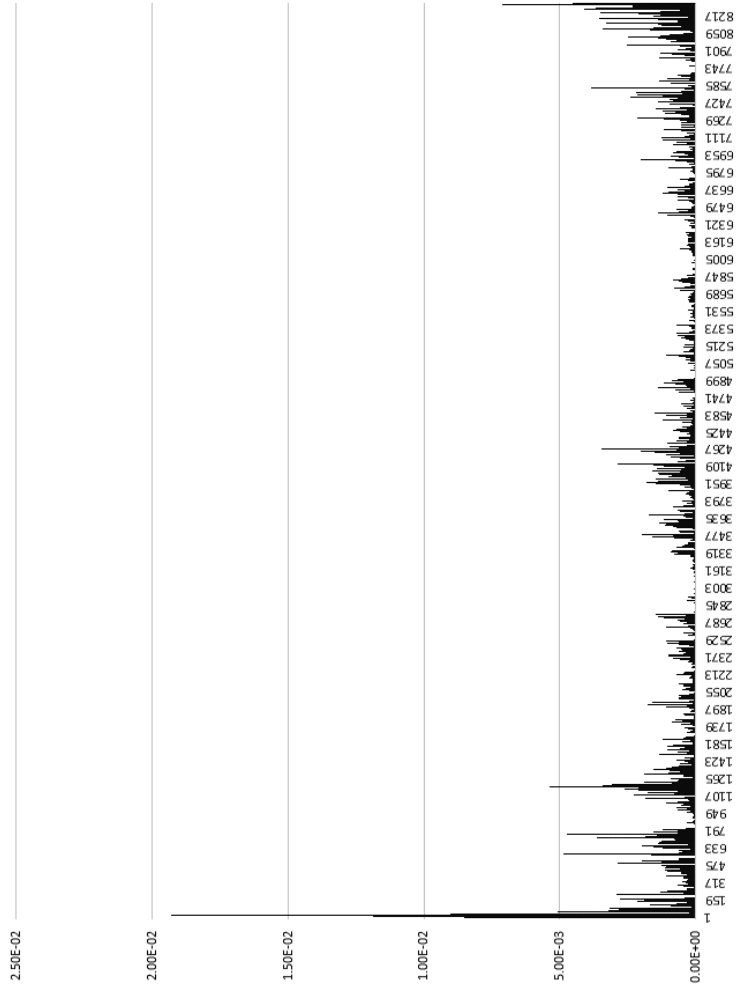

Fig.6. Duration_HS ; USD/JPY

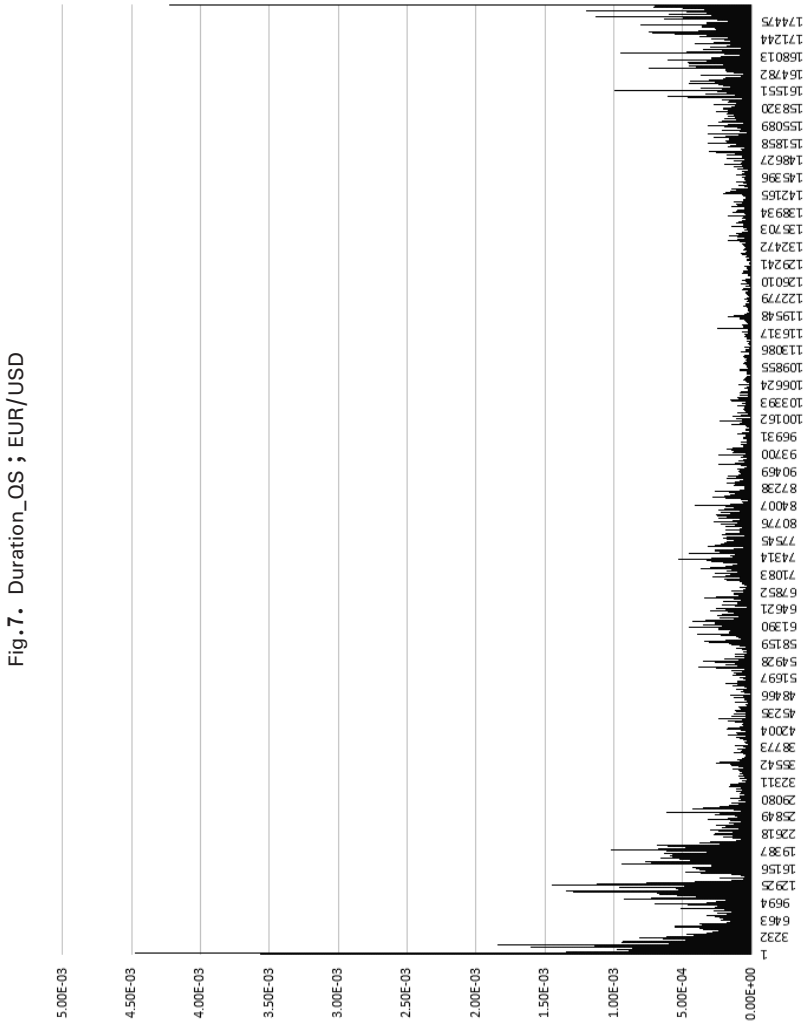

Fig.7. Duration_QS ; EUR/USD

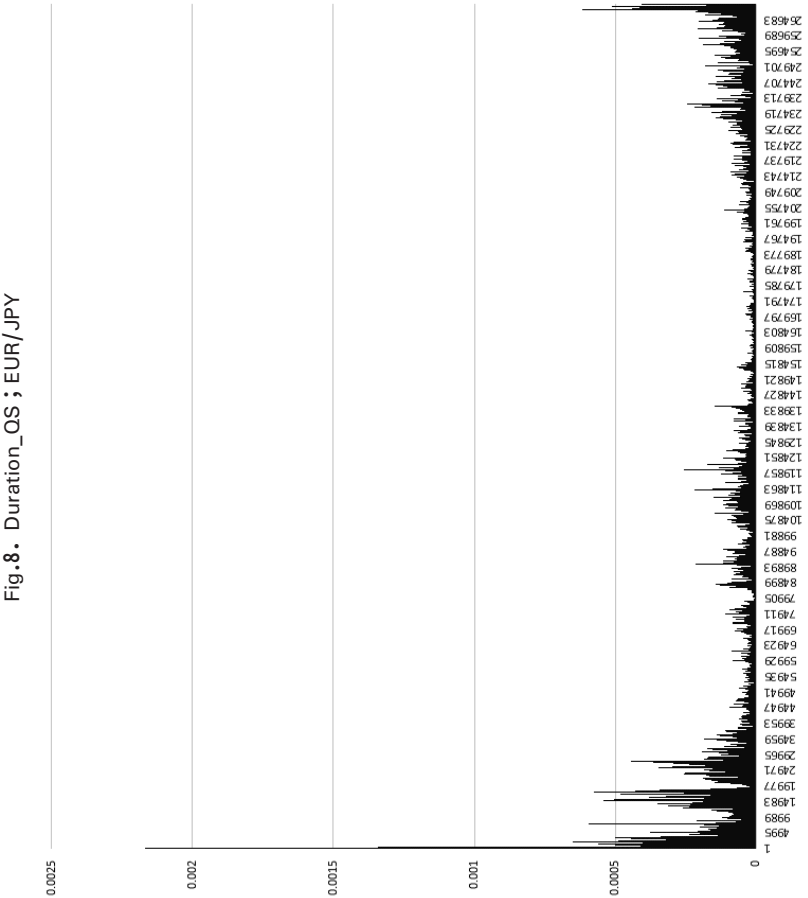

Fig.8. Duration_QS ; EUR/JPY

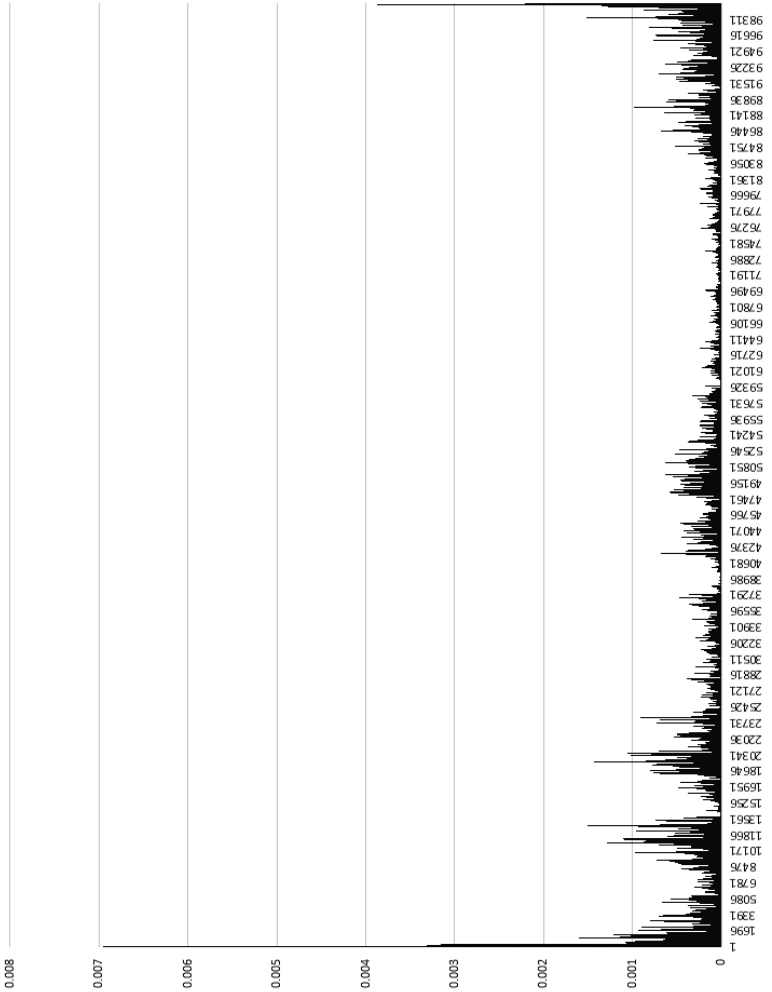

Fig.9. Duration_QS；USD/JPY

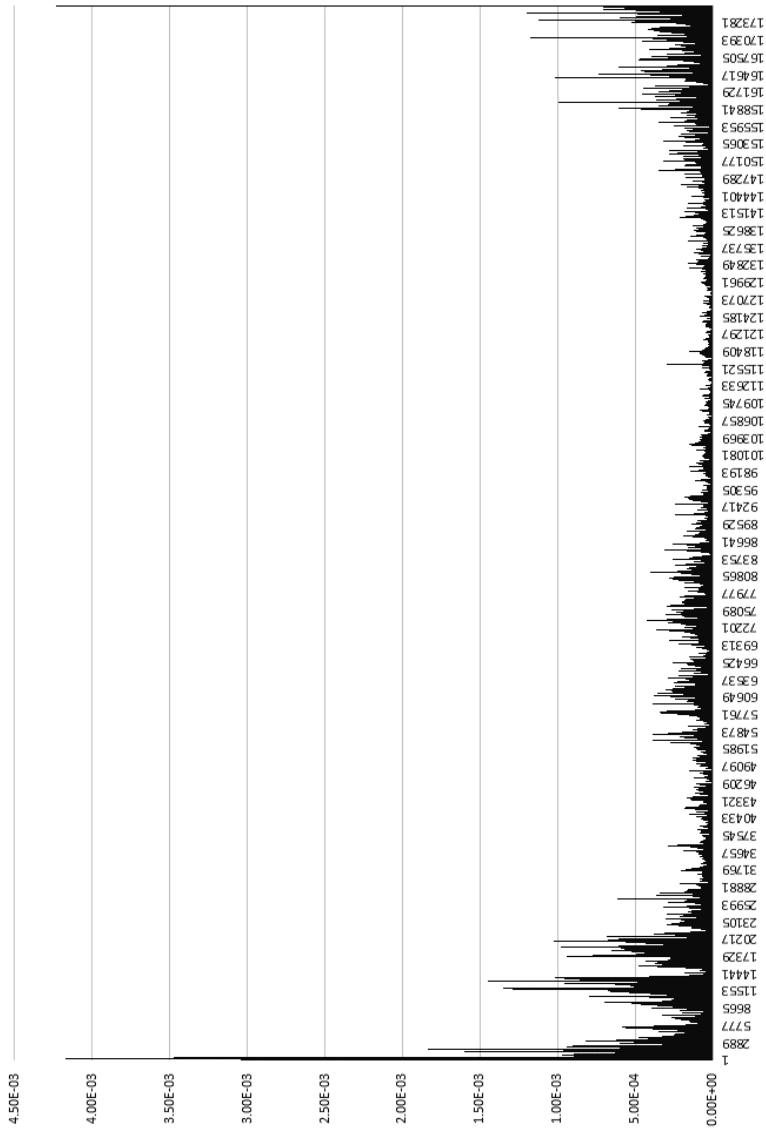

Fig.**10.** Duration_QD；EUR/USD

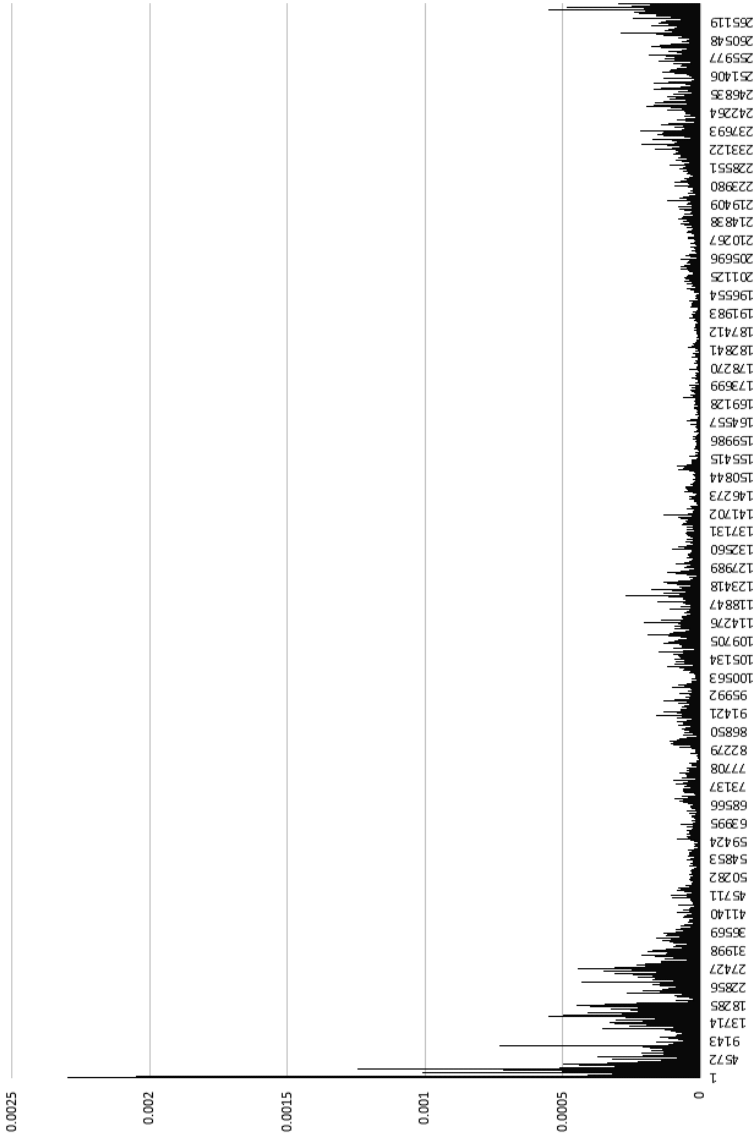
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Fig.11. Duration_QD ; EUR/USD

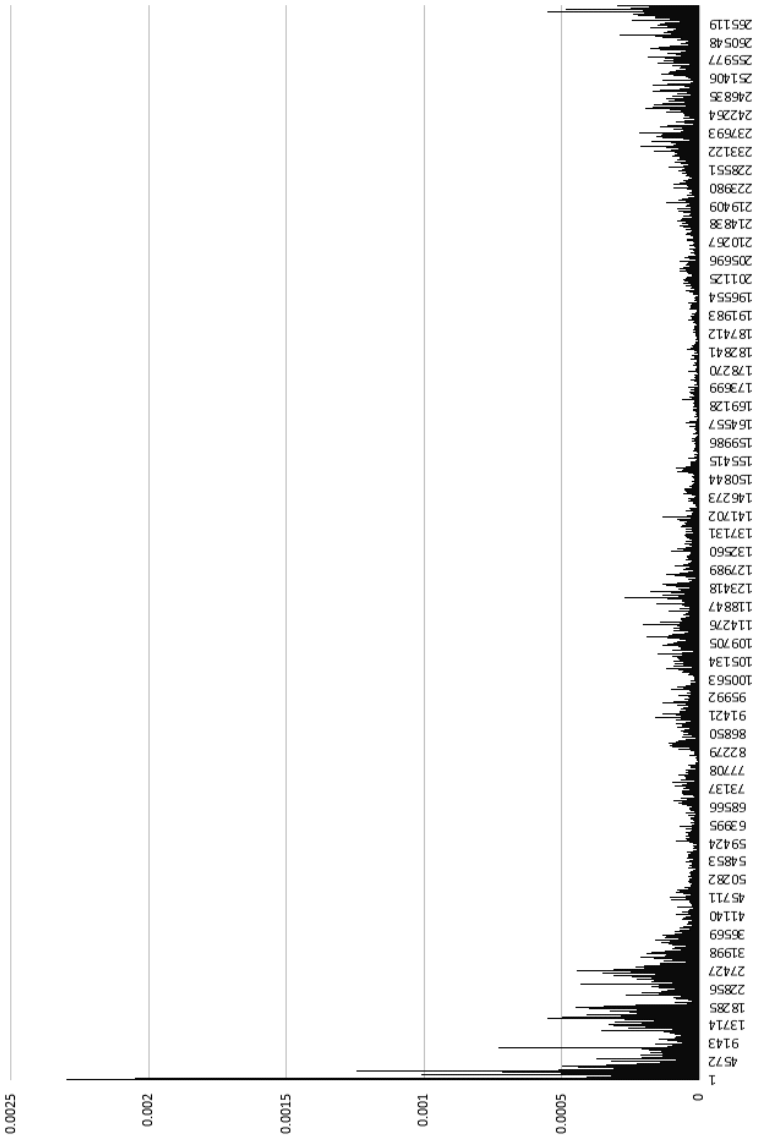

Fig.**12.** Duration_QD ; EUR/JPY

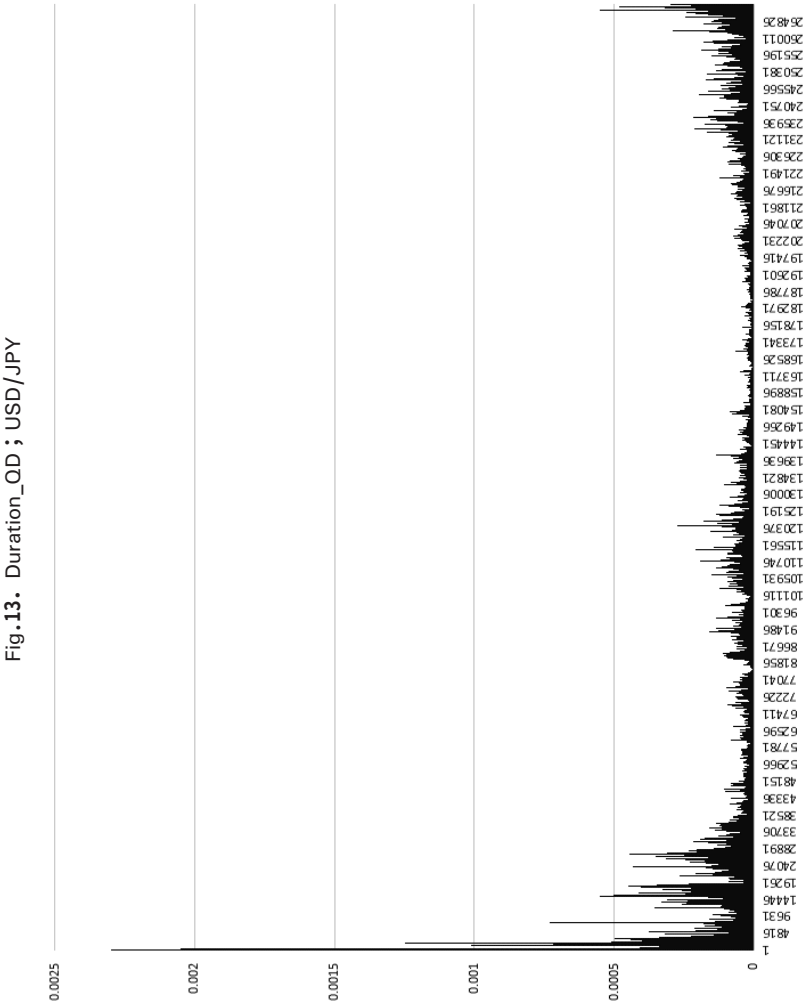
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Fig.13. Duration_QD ; USD/JPY