

# **Dynamics of the top of the order book in a global FX spot market**

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## **Abstract**

The order life time at the top of the order book is defined as the time between the order arrival at the top of the order book and its removal from the top of the order book. In this work, the average order life time in the EBS FX spot market is analyzed for two corresponding four-week periods in 2004 and 2005. The following currency pairs, EUR/USD, USD/JPY, USD/CHF, EUR/JPY, and EUR/CHF, are considered during the most liquid period of the working day, 7:00 – 17:00 GMT. Generally, the distribution of orders with a given life time at the top of the order book decays exponentially at short times. However this decay follows a power law at longer time periods. The crossover times between the two decay forms are estimated. It is shown that the decays have steepened and the order life time has become shorter in 2005. In particular, 47.9% of the EUR/USD orders and 34.7% of the USD/JPY orders live less than one second on the top of the order book. Two possible causes of the power-law asymptote are indicated: orders with amounts significantly higher than the average value and the specifics of credit relations among the EBS customers. The only exclusion from the described pattern is the order dynamics of EUR/CHF in 2005 that does not have an exponential decay.

*Keywords: high-frequency FX market, order life time.*

## **1 Introduction**

The global inter-bank FX spot market has dramatically changed since early 1990s when the electronic broking systems were introduced. Before that, a trader could either contact another trader directly (using telephone or a Reuters electronic system 2000) or trade via “voice brokers” who were collecting and matching the bid and offer orders over dedicated telephone lines. The electronic

broking systems do this matching at greatly increased speed and reduced cost. At present, the global inter-bank spot foreign exchange is overwhelmingly conducted via two electronic broking systems, EBS and Reuters 3000. While Reuters has significant market share in GBP-based currency pairs, EBS overwhelmingly dominates the electronic inter-bank spot EUR/USD and USD/JPY exchange. The daily transacted volume in the EBS market is approximately 120 billion USD. As a result, the EUR/USD and USD/JPY rates posted at any time on the EBS trading screens have become the reference prices quoted by dealers worldwide to their customers [1].

Yet, current empirical research of the high-frequency FX markets is overwhelmingly based on the Reuters indicative rates. The disadvantages of the indicative rates in comparison with the “firm” rates at which the inter-bank currency exchange is conducted are well documented (see e.g. [2, 3] for a review). In recent years, several studies of the high-frequency FX market based on the consolidated EBS proprietary data have been reported [1, 4 – 5]. However, analysis of many intriguing properties of the high-frequency market requires an access to the customer-sensitive data that currently cannot be made publicly available. Therefore we feel that disclosing some of the EBS “in-house” findings based on analysis of these intimate data will benefit both the EBS customers and the academic community.

We define the order life time at the top of the order book as the time between the order arrival at the top of the order book and its removal from the top of the order book.

This report describes the average life time of the orders at the top of the EBS order book for two four-week periods starting on Mondays, 13-Sep-2004 and 12-Sep-2005, respectively. The following currency pairs, EUR/USD, USD/JPY, USD/CHF, EUR/JPY, and EUR/CHF, are considered during the most liquid time of the working day, 7:00 – 17:00 GMT. We show that the distribution of orders with a given life time at the top of the order book generally decays exponentially at short times. However this decay follows a power law at longer time periods. The only exclusion from the described pattern is the order book dynamics of EUR/CHF in 2005 that does not have an exponential decay. The crossover times between the two decay forms are estimated and it is shown that the decays have steepened and the order life time has become shorter in 2005. In particular, 47.9% of the EUR/USD quotes and 34.7% of the USD/JPY quotes live less than one sec on the top of the order book. The report is organized as follows. The specifics of the EBS FX spot market pertinent to this work are listed in the next Section. The results and their discussion are presented in Section 3.

## **2 The EBS FX spot market**

The EBS system has several specifics that are important for this work. First, only the limit orders are accepted (no market orders may be submitted). The EBS system has two types of orders: quotes and hits. Quotes stay in the order book until they are filled or are interrupted; hits are automatically cancelled if they have no matching counterpart when they reach the market. Hence, a hit is always

a taker order while a quote may be either a maker order or a taker order. If a quote matches an order arriving the market later than this quote, the quote is a maker order. If a quote matches another quote that was present in the market before this quote arrived, this quote is a taker order. In the EBS market, only takers pay the transaction fees. Here we consider only the quote dynamics.

Orders in the EBS market are submitted in units of millions (M) of the base currency (the first currency in the name of the currency pair, e.g., USD for USD/JPY and EUR for EUR/USD). This may be worth to remember while considering the triangle arbitrage opportunities. Indeed, if one buys an amount of USD for 1M of EUR (say 1208300 USD according to the exchange rate on 20-Jan-2006), then transforming this entire amount of USD into e.g. CHF is tricky as only an integer number of millions of USD can be submitted in the EBS market for exchange with CHF.

Trading in the EBS market is allowed only between the counterparts that have bilateral credit. Every EBS customer establishes credit with all other EBS customers and can change its credit to other customers at any time. This implies that the EBS best prices (highest bid and lowest offer) may or may not be available to an EBS customer, depending on whether this customer has bilateral credit with the makers of the best prices. In fact, entire market depth available to an EBS customer is determined by its credit relations with all other EBS customers. Four types of prices on the both bid and offer sides are shown on the EBS trading screen. Besides the EBS best prices and the best available (due to the credit restrictions) prices, there are also credit-screened regular prices. The regular amount is a notional volume specific for each currency pair. In particular, it currently equals 15M of EUR for EUR/USD and 15M of USD for USD/JPY. If the currently available volume is less than the regular amount, it is also displayed on the EBS trading screen. For example, current EUR/USD best available offer and the regular offer are 1.2083 and 1.2086, respectively. Also, current best available volume is 9M. Then while trading the regular amount, 9M can be bought at 1.2083 and 6M can be bought at a rate higher than 1.2083 but not higher than 1.2086.

The EBS global market has three regional order matching processes, so-called arbitrators. These arbitrators are located in London (LN), New York (NY), and Tokyo (TY). Since the order arrival time is smaller for intra-regional networks than for inter-regional networks, the regional order books may somewhat vary. Indeed, consider a case when two bids with the same (new) best price are submitted at the same second by a London customer and a Tokyo customer. One may expect that the London quote will arrive at the top of the London order book while the Tokyo quote will land on the top of the Tokyo order book. Then if the London best quote is filled, the top of the London order book is changed while the top of the Tokyo order book remains the same (the Tokyo quote is now at the top of both the London and Tokyo order books).

The EBS primary historical data base contains chronologically ordered records of all events ever occurred in the EBS market. Restoring an order book at a given time from the historical data base requires sophisticated software that replicates important arbitrator functions.

### 3 Results and discussion

Three types of events remove a quote from the top of the order book:

- Quote is completely filled
- Quote is interrupted
- Quote is replaced with another one that has a better price

As it was indicated in the former Section, the regional order books can somewhat vary. Table 1 illustrates these differences for the period 3 Oct 2005 – 7 Oct 2005, 7:00 – 17:00 GMT. For a given currency pair, the percentages of filled, interrupted, and replaced quotes are very close in all three regions. Further, the data for NY are discussed. The estimates of the life time were done in seconds.

Table 1: Changes at the top of the EBS regional order books for the period 3 Oct 2005 – 7 Oct 2005 between 7:00 – 17:00 GMT.

		Total changes at the top	Filled, %	Replaced,%	Interrupted, %
EUR/USD	NY	181259	66.1	27.1	6.8
	LN	184697	66.8	26.6	6.6
	TY	173445	64.6	28.4	7.0
USD/JPY	NY	88999	53.2	34.3	12.5
	LN	90237	53.9	33.8	12.3
	TY	87969	52.6	34.8	12.6
USD/CHF	NY	78062	34.0	38.7	27.3
	LN	78031	34.1	38.6	27.3
	TY	77026	33.2	39.2	27.6
EUR/JPY	NY	58546	27.8	41.2	31.0
	LN	58807	28.2	41.0	30.8
	TY	58334	27.6	41.4	31.0
EUR/CHF	NY	34838	45.9	39.7	14.4
	LN	34965	46.0	39.6	14.4
	TY	34470	45.3	40.1	14.6

If all quotes “were created equal”, one might expect an exponentially decaying life time on the top of the order book, similarly to radioactive atom decay. Indeed, if some factors lead to removing N percent of quotes in the first second, the same N percent of the remaining quotes will be removed in the next second, and so on. However, our results show that the distribution of the quote life time follows an exponential decay only at short periods of time. With exclusion of EUR/CHF in 2005 (see discussion below), these periods span from two seconds for EUR/USD to five seconds for EUR/JPY. At longer times, the quote life time follows a power law. This can be understood as the quote life time depends not only on the market activity but also on the quote size and on

the creditability of its owner. Indeed, a quote with an amount notably exceeding an average value can stay at the top of the order book for some time until it is completely filled with smaller counterpart orders. Also, a quote submitted by a customer with a smaller credit may stay at the top of the order book for some time until someone with available bilateral credit is willing to match it.

We defined the crossover time between the exponential and power-law approximations of decay as the time at which the sum of the coefficients of determination,  $R^2$ , for the exponential fit and the power-law fit has a maximum. The analytical fits were estimated using the Microsoft Excel 2003 software.

The results of our analysis are summarized in Tables 2 and 3. Two most liquid currency pairs in the EBS market, EUR/USD and USD/JPY, have the same crossover time in 2004 and 2005 (2 sec for EUR/USD and 4 sec for USD/JPY). However decays for both these currency pairs have steepened in 2005. Namely, the percentage of EUR/USD quotes lived on the top of the order book for less than one second has increased from 44.8% to 47.9%. Similarly for USD/JPY, this percentage has changed from 30.9% to 34.7%. The decay of the quote life time at the top of the order book in 2005 is illustrated in Fig.1 and Fig.2 for EUR/USD and USD/JPY, respectively.

The most dramatic changes have occurred for less liquid currency pairs. In particular, the crossover times decreased from 7 sec to 3 sec for USD/CHF and from 8 sec to 5 sec for EUR/JPY. Moreover, the percentage of quotes that lived at the top of the order book less than one second almost doubled: from 22.3% to 32.3% for USD/CHF and from 18.6% to 26.9% for EUR/JPY. It should be noted also that these two currency pairs have significantly higher percentage of interrupted quotes at the top of the order book, particularly in 2005 (cf. 30.5% for USD/CHF and 32.0% for EUR/JPY versus 6.9% for EUR/USD and 12.7% for USD/JPY).

For the least liquid currency pair among those we considered, EUR/CHF, the percentage of quotes that lived at the top of the order book less than one second has also increased in 2005: from 21.4% to 25.1%. However, its decay did not follow the general pattern in 2005. Namely, while the exponential decay existed in 2004 at times greater than 6 sec, it was not found in 2005. As it can be seen in Figure 3, the empirical curve has a small hump in the region from 2 to 4 sec, which complicates its simple analytical fit. It should be noted also that the exponential decay may still exist at times lower than one second. In future we are planning to make similar estimates on a grid finer than the one-second grid.

Table 2: Quote life time at the top of the EBS order book for the period  
13 Sep 2004 – 8 Oct 2004, working days between 7:00 – 17:00 GMT.

2004	EUR/USD	USD/JPY	USD/CHF	EUR/JPY	EUR/CHF
Crossover time (T), sec	2	4	7	8	6
Exponential law ( $x \leq T$ )	$0.9140e^{-0.7054x}$	$0.4711e^{-0.4331x}$	$0.3195e^{-0.3179x}$	$0.2695e^{-0.2703x}$	$0.2643e^{-0.3015x}$
Exponent's $R^2$ ( $x \leq T$ )	0.9996	0.9988	0.9945	0.9918	0.9914
Power law ( $x > T$ )	$0.7939x^{-2.1315}$	$0.8599x^{-1.8797}$	$0.9693x^{-1.7780}$	$1.2574x^{-1.8333}$	$0.4521x^{-1.4094}$
Power law's $R^2$ ( $x > T$ )	0.9931	0.9949	0.9954	0.9943	0.9969
Life time < 1 sec, %	$44.8 \pm 0.2$	$30.9 \pm 0.3$	$22.3 \pm 0.3$	$18.6 \pm 0.4$	$21.4 \pm 0.1$
Filled, %	$65.5 \pm 0.3$	$52.1 \pm 0.5$	$33.5 \pm 1.0$	$26.6 \pm 1.0$	$41.1 \pm 0.1$
Replaced, %	$28.1 \pm 0.2$	$36.3 \pm 0.2$	$42.9 \pm 0.4$	$44.4 \pm 0.3$	$42.1 \pm 0.1$
Interrupted, %	$6.4 \pm 0.1$	$11.5 \pm 0.3$	$23.6 \pm 0.7$	$29.0 \pm 0.7$	$16.8 \pm 0.2$

Table 3: Quote life time at the top of the EBS order book for the period  
12 Sep 2005 – 7 Oct 2005, working days between 7:00 – 17:00 GMT.

2005	EUR/USD	USD/JPY	USD/CHF	EUR/JPY	EUR/CHF
Crossover time (T), sec	2	4	3	5	-
Exponential law ( $x \leq T$ )	$1.041e^{-0.7763x}$	$0.5149e^{-0.4746x}$	$0.5422e^{-0.5107x}$	$0.3867e^{-0.3818x}$	-
Exponent's $R^2$ ( $x \leq T$ )	1.000	0.9927	0.9915	0.9912	-
Power law ( $x > T$ )	$0.7796x^{-2.1594}$	$0.8865x^{-1.9038}$	$0.6702x^{-1.7684}$	$0.8289x^{-1.7585}$	$0.3029x^{-1.255}$
Power law's $R^2$ ( $x > T$ )	0.9896	0.9913	0.9897	0.9910	0.9897
Life time < 1 sec, %	$47.9 \pm 0.6$	$34.7 \pm 0.4$	$32.3 \pm 1.1$	$26.9 \pm 1.3$	$25.1 \pm 0.4$
Filled, %	$65.8 \pm 0.2$	$53.1 \pm 0.3$	$31.0 \pm 1.1$	$27.3 \pm 1.4$	$44.8 \pm 0.5$
Replaced, %	$27.3 \pm 0.2$	$34.2 \pm 0.1$	$38.5 \pm 0.4$	$40.8 \pm 0.4$	
Interrupted, %	$6.9 \pm 0.1$	$12.7 \pm 0.4$	$30.5 \pm 1.2$	$32.0 \pm 1.7$	

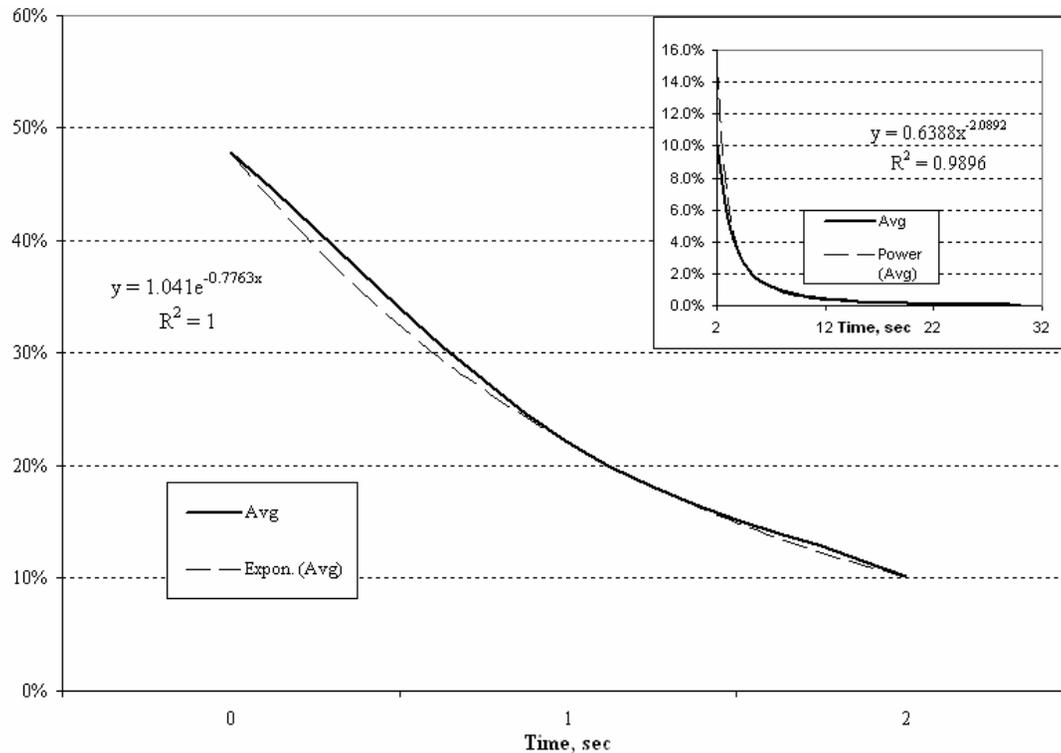


Figure 1: Distribution of the EUR/USD quote life time at the top of the EBS order book (12 Sep 05 – 7 Oct 05, working days, 7:00 – 17:00 GMT)

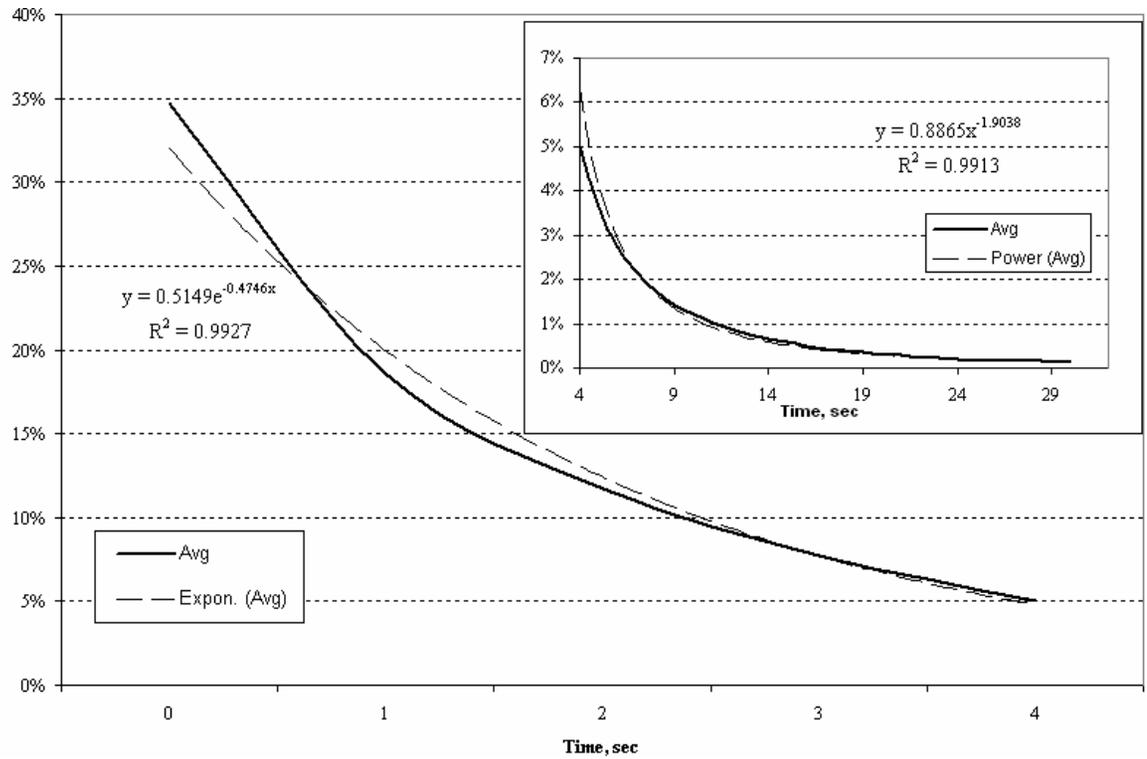


Figure 2: Distribution of the USD/JPY quote life time at the top of the EBS order book (12 Sep 2005 – 7 Oct 2005, working days, 7:00 – 17:00 GMT)

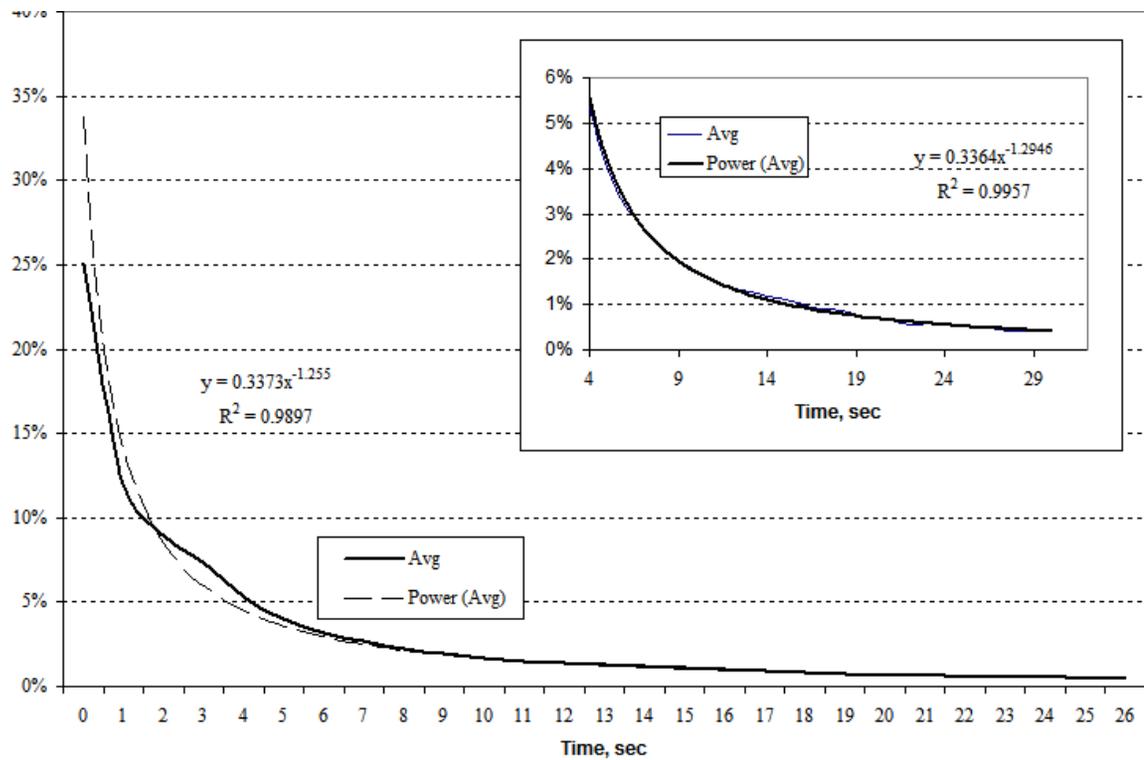


Figure 3: Distribution of the EUR/CHF quote life time at the top of the EBS order book (12 Sep 2005 – 7 Oct 2005, working days, 7:00 – 17:00 GMT)

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