**Title: Comprehensive high-resolution analysis on behavior of market participants in the FX market**

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As a result of both development and spread of Information and Communication Technology (ICT) one can conduct both high resolution and comprehensive analysis on states of participants in financial markets by means of high-frequency financial data [1, 2]. Several researchers in econometrics, econophysics, and finance pay significant attention to fat-tailsness in probability density functions for log returns of financial commodities [3, 4]. More recently in order to understand the price movements in the financial markets more precisely several researchers noticed importance of understanding of quotation behavior as precursor states of trading and study on price formation mechanisms [5, 7, 6].

The aim of the present article is to propose a method to quantify and visualize attentions of market participants to financial commodities in order to see and know states of financial markets. Specifically in this article we focus on the FX market and attempt to comprehensively visualize the attention of market participants in the FX market by using quotation activities extracted from high-resolution data recorded in an electronic broking system.

Consider networks consisting of nodes (agents) which exchange constituents – substances, information, and so on –. We assume that constituents are transmitted from one node to the other. If a constituent is exchanged between two nodes then we suppose that these nodes should be connected.

Menezes and Barabási propose the method to quantify centrality of nodes for such networks from multiple time series of constituents' flows [8]. Suppose one can observe constituents at each node and count their presence with an interval of $\Delta(>0)$ at each node. Defining $f_i(t)$ as the constituents' flows at the $i$-th node $(i = 1, 2, \ldots, N)$ in $[t\Delta, (t+1)\Delta] \quad (t = 1, 2, \ldots, T)$ the centrality of the $i$-th node may be estimated as

$$A_i = \frac{\sum_{t=1}^{T} f_i(t)}{\sum_{t=1}^{T} \sum_{i=1}^{N} f_i(t)}. \tag{1}$$

This estimator originates with the random walk centrality (RWC) proposed by Noh and Rieger [9]. The RWC is based on stationary probability distributions for constituents which exist at each node. If many constituents exist at a node then it should seem to be an important node.

Under the assumption that the attention of market participants to the exchangeable currency pairs can be estimated as RWCs $A_i$ are computed for every day by using quotation frequencies extracted from high-resolution data provided by ICAP EBS. The reason why the RWC is adopted in order to quantify the

Table 1: The list of currency pairs which is exchangeable in the electronic broking system of the ICAP EBS. The abbreviation of currency name is based on ISO 4217.

| Abbreviation | Currency name | | Abbreviation | Currency name |
|---|---|---|---|---|
| AUD | Australia Dollar | | HUF | Hungarian Forint |
| CHF | Swiss Franc | | ISK | Iceland Krona |
| EUR | Euro | | NOK | Norwegian Krone |
| GBP | Great Britain Sterling | | PLN | Poland Złoty |
| NZD | New Zealand Dollar | | SEK | Swedish Krona |
| USD | United States Dollar | | SKK | Slovak Koruna |
| XAG | Silver | | ZAR | South African Rand |
| XAU | Gold | | CAD | Canadian Dollar |
| XPD | Palladium | | HKD | Hong Kong Dollar |
| XPT | Platinum | | MXN | Mexico Peso |
| JPY | Japanese Yen | | RUB | Russian Ruble |
| CZK | Czech Koruna | | SGD | Singapore Dollar |
| DKK | Danish Krone | | | |

attention of market participant is because this indicator can estimate quotation density in the FX market from multiple time series of quotation activities.

The quotation activity is defined as the number of quotation which market participants enter into the electronic broking system per minute. The exchangeable currency pairs [1] consisting of 21 currencies and 4 commodities which are listed in Tab. 1

The graphical network representation consisting of nodes which show currencies and weighted links which show exchangeable pairs and their attentions from market participants is shown in Fig. 1. From this networks we can find that three major currencies (USD, EUR, and JPY) are mainly quoted and that large quotation activities sometime appear in NZD/AUD, EUR/CHF, EUR/GBP, USD/CAD, and USD/PLN. According to the BIS triennial central bank survey of foreign exchange and derivatives market activity in 2007 [10], it is reported that shares of turnover by currency pairs are 27 % (USD/EUR), 13 % (USD/JPY), 12 % (USD/GBP), 6 % (USD/AUD), 5 % (USD/CHF), 4 % (USD/CAD), 2 % (USD/SEK), 2 % (EUR/JPY), 2 % (EUR/GBP), 2 % (EUR/CHF), and 27 % (other currency pairs), respectively. Results obtained from the proposal method are almost good agreement with the share of turnover reported by BIS.

[1] The exchangeable currency pairs are AUD/NZD, AUD/USD, CHF/JPY, EUR/CHF, EUR/CZK, EUR/DKK, EUR/GBP, EUR/HUF, EUR/ISK, EUR/JPY, EUR/NOK, EUR/PLN, EUR/SEK, EUR/SKK, EUR/USD, EUR/ZAR, GBP/USD, NZD/USD, USD/CAD, USD/CHF, USD/HKD, USD/JPY, USD/MXN, USD/PLN, USD/RUB, USD/SGD, USD/ZAR, XAG/USD, XAU/USD, XPD/USD, XPT/USD, GBP/JPY

The centrality of USD/JPY, USD/EUR, AUD/NZD, and USD/PLN for a period from June 1st to August 31st 2007 (GMT) is shown in Fig. 2. The centrality of USD/JPY has extremely large values at 6/24, 7/7, 7/21, and 7/30. The centralities of EUR/USD maintains 0.14 during the observation period. The centrality of AUD/NZD has large values before 6/23. The centrality of USD/PLN periodically behaves.

From application of the proposal method to visualization by using the ICAP EAS high resolution data the following facts are found: (1) several pairs to which many participants pay attention or for which they enter many quotations exits and others attract less their attention. (2) the attention of market participants to currency pairs temporally varies.

The proposed method would be useful to assist market participants to both intuitively and comprehensively understand states of the FX market. Moreover computational complexity of this technique is less than that of calculating correlation matrices and extracting network structure from them [11, 12]. And also recent computational ability and storage capacities are enough to implement this algorithm, to store the data, and to handle the data in real time. Therefore the proposal method would be contribute to even use real time monitoring of the FX market if the real time high-resolution data is available.

The comprehensive high-resolution monitoring of financial activities based on a physical point of view (econphysical perspective) is expected to open a new window in the field of both financial engineering and Informatics.

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## References

[1] V. Plerou, P. Gopikrishnan, B. Rosenow, L.A. Nunes, N. Amaral and H.E. Stanley, "Universal and Nonuniversal properties of cross correlations in financial time series", Physical Review Letters, 83 (1999) pp. 1471–1474.

[2] A.-H. Sato, "Application of spectral methods for high-frequency financial data to quantifying states of market participants", Physica A, 387 (2008) pp. 3960–3966.

[3] R. Mantegna and H.E. Stanley, *An Introduction to Econophysics Correlations and Complexity in Finance* (Cambridge University Press, Cambridge, 2000).

[4] T. Mizuno, S. Kurihara, M. Takayasu, and H. Takayasu, "Analysis of high-resolution foreign exchange data of USD-JPY for 13 years", Physica A, 324 (2003) pp. 296–302.

[5] M. Melvin, and X. Yin, "Public information arrival, exchange rate volatility, and quote frequency", The Economic Journal, 110 (2000) pp. 644–661.

[6] D. Challet and R. Stinchcombe, "Limit order market analysis and modelling: on a universal cause for over-diffusive prices", Physica A, 324 (2003) pp. 141–145.

[7] A.-H. Sato, "Characteristic time scales of tick quotes on foreign currency markets: an empirical study and agent-based model", The European Physical Journal B, 50 (2006) pp. 137–140.

[8] M.A. de Menezes, and A.-L. Barabá si, "Separating internal and external dynamics of complex systems", Physical Review Letters, 93 (2004) 068701.

[9] J.D. Noh and H. Rieger, "Random walks on complex networks", Physical Review Letters, 92 (2004) 118701.

[10] Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in 2007 (http://www.bis.org/publ/rpfxf07t.pdf)

[11] T. Aste, and T.D. Matteo, "Dynamical networks from correlations", Physica A, 370 (2006) pp. 156–161.

[12] M.J. Naylor, L.C. Rose, B.J. Moyle, "Topology of foreign exchange markets using hierarchical structure methods", Physica A, 382 (2006) pp. 199-208.

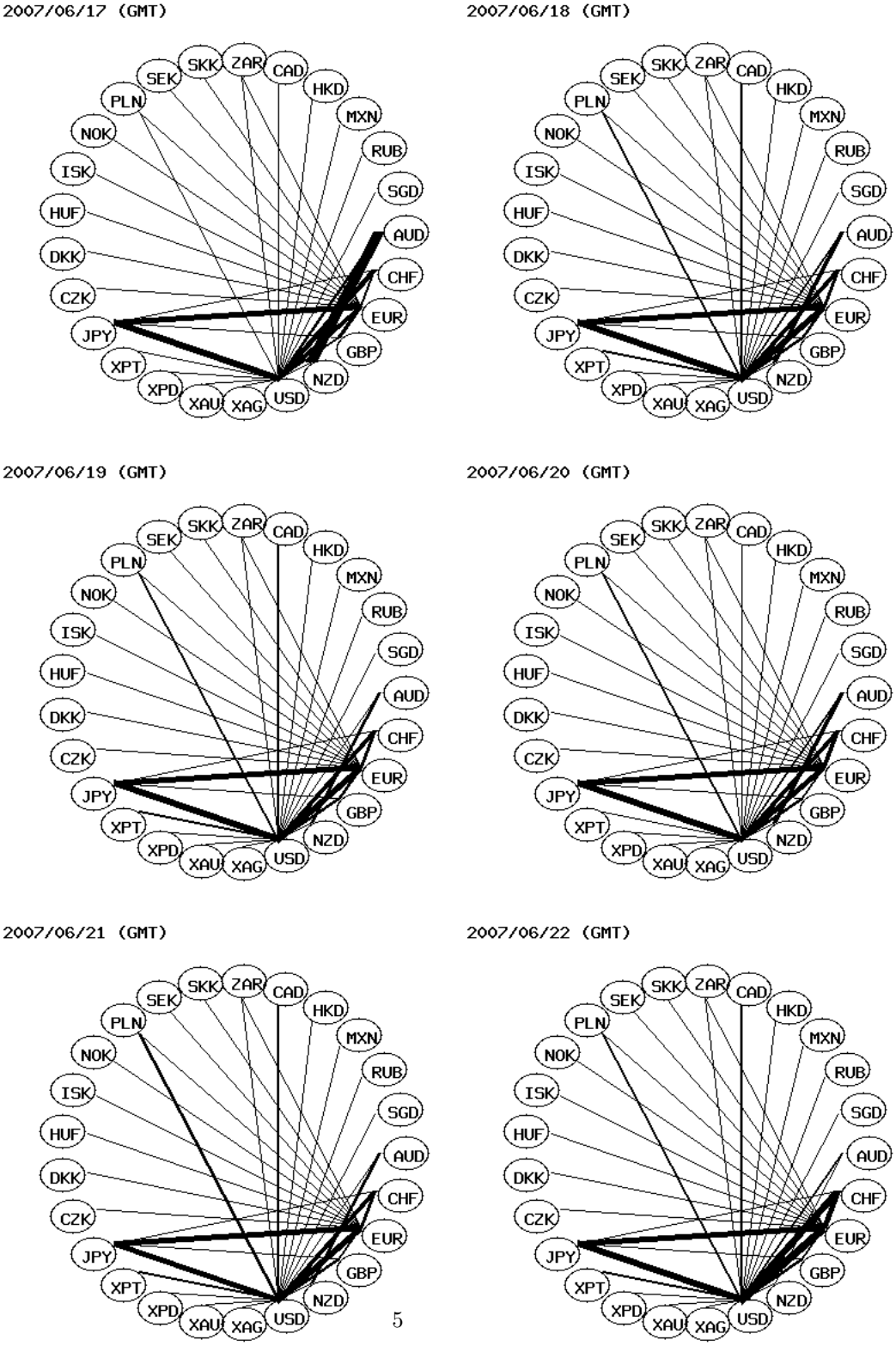


Figure 1: Network graphical representation of exchangeable currency pairs and their attention estimated as the centrality. Nodes represent currencies, and weighted links connected between nodes currency pairs. The thick/thin lines show currency pairs with high/low centrality.

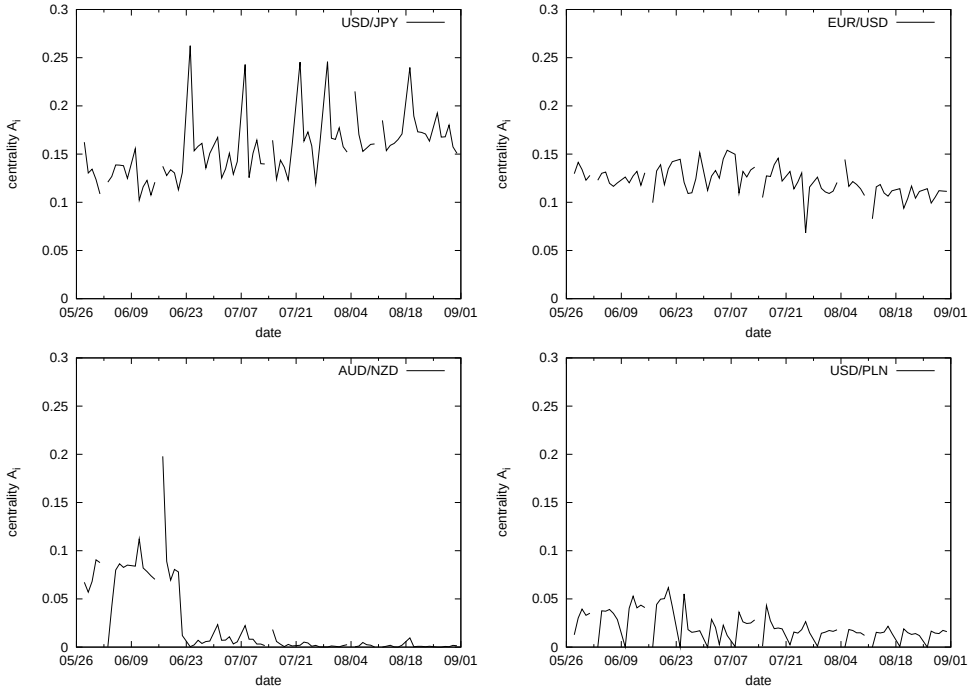


Figure 2: Time series of centralities for USD/JPY, USD/EUR, AUD/NZD, and USD/PLN for a period from 1st June to 31st August 2007 (GMT).