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Are EUR and GBP different words for the same currency?

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Abstract. The British Pound (*GBP*) is not part of the Euro (*EUR*) monetary system. In order to find out arguments on whether *GBP* should join the *EUR* or not correlations are calculated between *GBP* exchange rates with respect to various currencies: *USD*, *JPY*, *CHF*, *DKK*, the currencies forming *EUR* and a reconstructed *EUR* for the time interval from 1993 till June 30, 2000. The distribution of fluctuations of the exchange rates is Gaussian for the central part of the distribution, but has fat tails for the large size fluctuations. Within the *Detrended Fluctuation Analysis* (*DFA*) statistical method the power law behavior describing the root-mean-square deviation from a linear trend of the exchange rate fluctuations is obtained as a function of time for the time interval of interest. The *time-dependent exponent evolution* of the exchange rate fluctuations is given. Statistical considerations imply that the *GBP* is already behaving as a true *EUR*.

PACS. 05.45.Tp Time series analysis – 05.45.Gg Control of chaos, applications of chaos – 74.40.+k Fluctuations (noise, chaos, nonequilibrium superconductivity, localization, etc.) – 95.10.Fh Chaotic dynamics

1 Historical introduction

This paper, even though it can be considered as somewhat politically motivated and only timely pertinent, is essentially a practical study in econophysics. It develops previous considerations [1,2], and subsequent comments [3,4]. It is based on questions on *e.g.* how inspired marketing may be needed to get the British to accept the Euro [5]. The British public seems hostile. Between a Mori poll a couple of years ago, and one in November 2000, the no's climbed from 56% to 71%. Thus pedestrian considerations, like when these authors travel from country to country exchanging currencies for registering at meetings, or buying books are in order. The paper is also timely because the Prime Minister T. Blair in early February 2001 said that he would call for a referendum on joining the Euro within two years of a Labour party election victory. The conditions are well known [6].

The big problem for the Euro camp is the emotional argument (abolishing the sterling). It is very difficult to sell *advantages* through rational arguments. It seems that the people are shouting for a football team, and the business elite wish to surrender sovereignty, says Mr. Byrne, chief executive of Weber Shandwick Public Affairs, as quoted by Tomkins [5]. To argue in favor of the Euro might be a hard task, but it is simply true that the Britons will use the Euro, whatever their taste, in 2005, whether they like it or not. Mr. Draper, as quoted by Tomkins in reference [5] considers that it has to be emphasized that it makes no difference if all pounds turned into Euro [5]. It is just another name for money. This paper shows just *that* from a currency exchange point of view. The paper does not contain any analysis nor criticism of rational or not arguments toward a possible growth policy, whatever that means, nor about how to make Britain more productive [7], because of exchange rate control [8].

Of course, from a financial and monetary policy, one can wonder what governments should do. In 1961 Mundell [10] asked whether it is advantageous to relinquish monetary sovereignty in favor of a common currency? For fixed exchange rates, the central banks must intervene on the currency market in order to satisfy the public demand for foreign currency at this exchange rate. As a result, the central banks loose some control of the money supply which adjusts itself to the domestic liquidity. To implement independent national monetary policy by means of so-called *open market operations* becomes rather futile [8]: neither the interest rate nor the exchange rate can be affected. The more so when the Central Bank is independent, *e.g.* as wished [7] by the New Labour when it came to power in 1997 and when instituting a new long term monetary and fiscal discipline. Sometimes it is thought that UK is more vulnerable inside euro [9].

A currency union as early as 1960 with fixed exchange rates existed within the so-called Bretton Woods System. International capital movements were highly curtailed, in

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particular by extensive capital and exchange rate controls. It was noticed that due to high capital mobility in the world economy, such regimes with a temporarily fixed, but adjustable, exchange rate were not robust. Whence several governments have some fear about joining a system like EUR. Often psychological or demagogic arguments are more relevant to the public than real economic ones, – see the case of Denmark. The Blair Government supports the principle of joining the single currency, if that is in the national economic interest but considers *not to be ready yet*. Can the exchange rates serve as arguments? We have searched for statistical correlations between various currencies, *e.g.* USD, JPY, CHF, DKK, EUR and GBP exchange rate fluctuations, in order to obtain some *at least numerical* argument.

Hereby one of the questions raised is how the GBP has fluctuated with respect to a $false$ EUR, made of an equally weighted linear superposition of the 11 currencies forming EUR, and how GBP/EUR, GBP/USD, etc. fluctuates since Jan. 01, 1999. Essentially it has been first searched whether the fluctuations did change after the formal introduction of EUR. Next it has been observed whether there is an *a posteriori* mathematical evidence for fluctuation correlations between GBP, EUR and the still presently national currencies. The considered time interval is Jan. 01, 1993 to June 30, 2000.

The *Detrended Fluctuation Analysis* (DFA) is used [11]. The α exponent characterizing the power law over the longest possible scaling range pertaining to this study is obtained. The analysis differs from that of Brooks and Hinich [12] who used a nonlinear Granger causality test for the GBP exchange rates over 20 years (1974–1994). The technique can, as shown by Renault *et al.* [13], sometimes lead to spurious causalities. Thus we use a time dependent DFA [14], in order to obtain a so-called correlation matrix when eliminating the time as a series parameter. The data is summarized through the mean, the variance and the median of the local α exponents. Some *financial policy statement* and *other considerations* arising from our observations serve as conclusions.

2 Experimental data

The conversion rates of the EUR participating countries were fixed [6] by political agreement based on the bilateral market rates of December 31, 1998. Using these rates [15], one Euro (EUR) can be represented [16–18] as a weighted sum of the eleven currencies C_i, $i = 1, 10$:

$$1EUR = \sum_{i=1}^{10} (\delta_{i,2} + 1) \frac{\gamma_i}{11} C_i \qquad (1)$$

where γ_i are the conversion rates and C_i denote the respective currencies, *i.e.* Austrian Schilling (ATS, $i = 1$), Belgian Franc (BEF, $i = 2$), German Mark (DEM, $i = 3$), Spanish Peseta (ESP, $i = 4$), Finnish Markka (FIM, $i = 5$), French Franc (FRF, $i = 6$), Irish Pound (IEP, $i = 7$), Italian Lira (ITL, $i = 8$), Dutch Guilder (NLG, $i = 9$), Portuguese Escudo (PTE, $i = 10$). In view of the financial identity of the Luxembourg Franc (LUF), with the Belgian Franc (BEF), the latter is weighted by a factor of two, whence the δ Kronecker symbol in the above equation. In order to study correlations in the EUR/GBP exchange rate, the EUR existence can be artificially extended backward, *i.e.*, before Jan. 01, 1999 and thereby defining an artificial EUR before its birth [16]. A data series of GBP exchange rates with respect to EUR is constructed following the linear superposition rule:

$$1GBP/EUR = \sum_{i=1}^{10} (\delta_{i,2} + 1) \frac{\gamma_i}{11} (GBP/C_i). \qquad (2)$$

Since the number of data points of the exchange rates (ExR) for the period starting Jan. 1, 1993 and ending Dec. 31, 1998 is different for the eleven currencies, due to different national and bank holidays a linear interpolation has been used for the days when the banks are closed and official exchange rates are not defined in some countries. The number N of data points as equalized is $N = 1902$, spanning the time interval from January 1, 1993 till June 30, 2000[1].

The normalized and true EUR/GBP exchange rates so reconstructed are given in Figure 1a–b. For normalization purpose of the exchange rate Oct. 2, 1996 has been chosen as a typical day, *i.e.* are given in Table 1. Other ExR of interest are given in Table 2 and in Figure 2. Recall that we only consider the exchange rates of the GBP and the EUR with respect to different currencies outside the Euro system, like CHF, DKK, JPY and USD. The Swiss Frank (CHF) is a currency of a European country which is not part of the European Union, but is usually a reference currency. The Danish Kronna (DKK) represents a currency for a country which belongs to the European Union but is not part of the Euro system. The USD and JPY are well known major currencies outside Europe.

It is known [17] (see Fig. 1 also) that ExR like EUR/CHF and EUR/DKK are pretty stable across the transition to the EUR. However it seems that the ExR with respect to GBP has been much more sensitive to the transition, with a noticeable decay of the EUR value after Jan. 01, 1999. See the 1995 bump of ITL, and dips at the end of 1993 for ATS, BEF, DEM and NLG ExR with respect to GBP, the rate evolution being rough. The ESP, FIM, and ITL seem currencies following weakly the ExR majority (and the ExR statistical mean) evolution.

Note in Figure 2 that GBP/CHF and GBP/DKK fluctuate with time in a similar fashion, while GBP/USD is rather stable. The exchange rate of GBP with respect to JPY is rather different with a bump beginning in 1995 and a dip near the end of 1998 just before introducing the real Euro.

[1] This last day was chosen for the studies in order to remain coherent and avoid a possible spurious effect arising from the Greek Drachma (GRD), introduced as a supplementary currency in EUR on June 19, 2000.

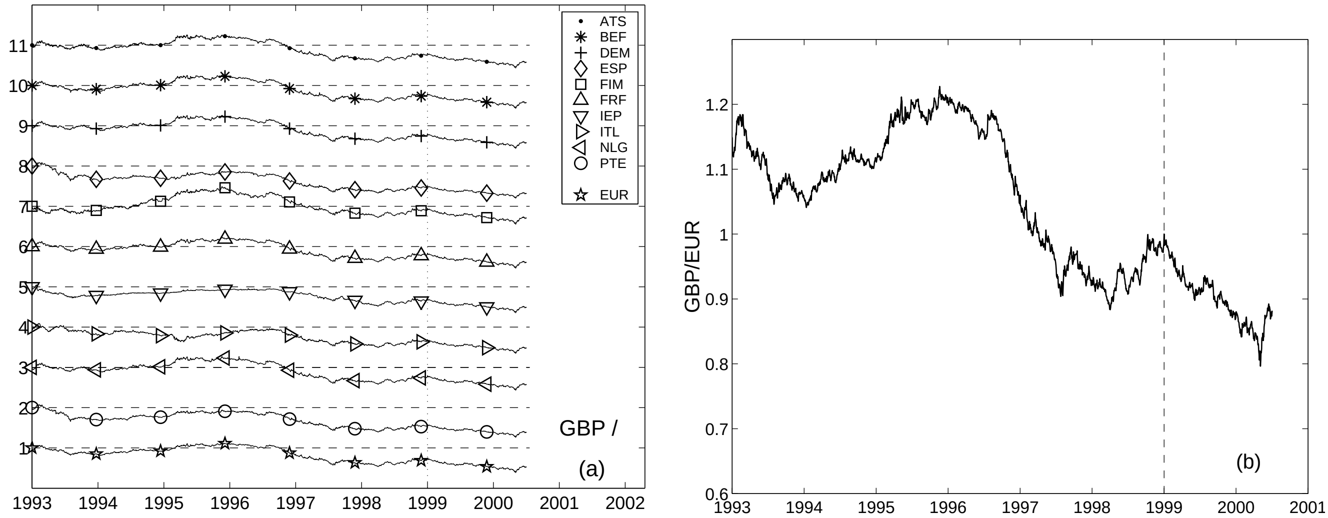

Fig. 1. (a) Normalized and (b) true EUR and currencies forming the EUR exchange rates with respect to GBP between Jan. 01, 1993 and June 30, 2000. The exchange rates on (a) are artificially multiplied by a factor of two and then displaced along the vertical axis in order to make the fluctuations to become noticeable. For normalization purposes the exchange rates on Jan. 1, 1993 on (a) are assumed to be equal to one.

Table 1. Indicative values, for normalization purposes of GBP exchange rate on Oct. 2, 1996, *e.g.* 1 $GBP \simeq 16.87$ ATS. Numerical values of DFA-α exponent for EUR-forming currency exchange rates. The scaling time interval is *ca.* one year. Estimated values of the exponent of the power-law in the tail of the distribution of fluctuations for EUR-forming currency exchange rates. The Kolmogorov-Smirnov (KS) parameter indicating Gaussian deviation of the studied distributions.

C_i	ATS	BEF	DEM	ESP	FIM	FRF	IEP	ITL	NLG	PTE	EUR
ExR	16.87	49.383	2.3976	201.59	7.1587	8.1241	0.9792	2372.0	2.6903	243.61	1.2234
α	0.47	0.47	0.50	0.51	0.46	0.47	0.41	0.46	0.49	0.45	0.46
	±0.02	±0.02	±0.02	±0.02	±0.02	±0.02	±0.03	±0.02	±0.02	±0.02	±0.02
μ	4.10	3.30	3.85	3.67	3.98	3.98	4.65	3.30	3.98	3.56	4.02
KS	0.058	0.050	0.052	0.039	0.046	0.043	0.074	0.040	0.050	0.051	0.046

Table 2. Indicative values, for normalization purposes of GBP exchange rate on Oct. 2, 1996, *e.g.* 1 $GBP \simeq 1.57$ USD. Numerical values of DFA-α exponent for GBP exchange rates with respect to CHF, DKK, JPY and USD. The scaling time interval is *ca.* one year. Estimated values of the exponent of the power-law in the tail of the distribution of fluctuations for GBP exchange rates. The Kolmogorov-Smirnov (KS) parameter indicating Gaussian deviation of the studied distributions.

B_i	CHF	DKK	JPY	USD
ExR	1.97	9.20	175.30	1.57
α	0.51 ± 0.02	0.49 ± 0.02	0.53 ± 0.02	0.48 ± 0.02
μ	3.57	3.32	2.91	4.32
KS	0.044	0.047	0.043	0.053

3 Distribution of the fluctuations

The distributions of the exchange rate fluctuations for GBP/EUR and GBP/C_i are shown in Figure 3a–k for the time interval of interest. The distributions of the exchange rate fluctuations for GBP with respect to the other currencies are shown in Figure 4 for the time interval of interest. The central part of each distribution, *i.e.* the smallest fluctuations, is close to a Gaussian. A Kolmogorov-Smirnov (KS) test has been made to distinguish the

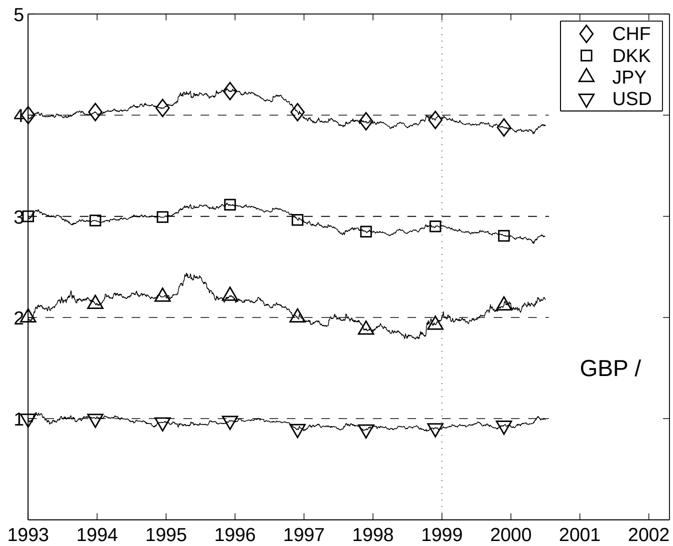

Fig. 2. Normalized GBP exchange rates with respect to CHF, DKK, JPY, USD between Jan. 01, 1993 and June 30, 2000. For normalization purposes the exchange rates on Jan. 1, 1993 are assumed to be equal to one.

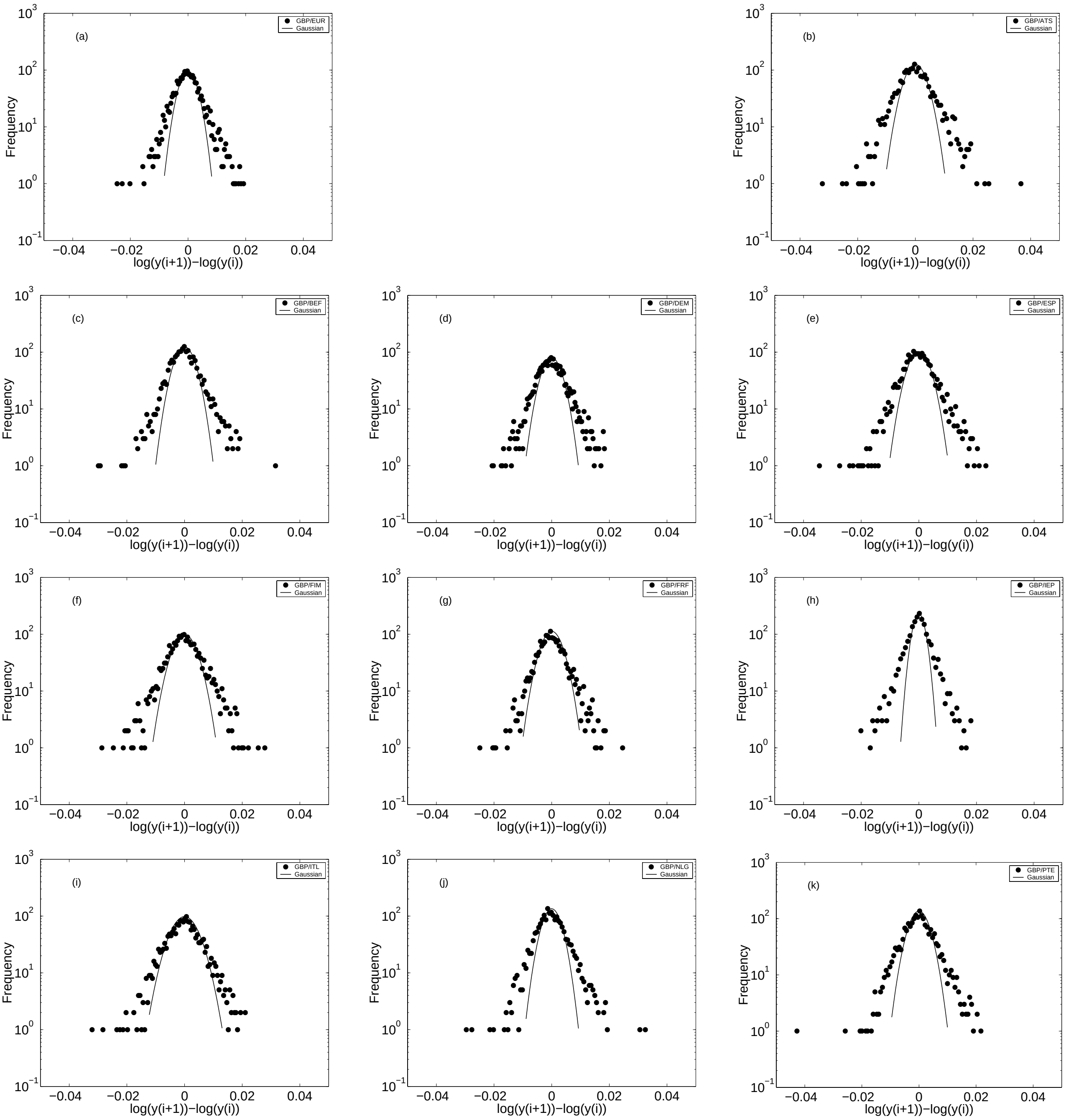

Fig. 3. Distributions of the exchange rate fluctuations for (a) GBP/EUR, and (b–k) GBP/C_i for data in Figure 1.

deviation from a Gaussian, – the KS parameter being given in Table 1 and Table 2. The tails of the distributions, *i.e.* the large fluctuations, strictly depart from the normal distribution. Such tails usually [19] have a slope markedly different from -2. These so-called fat tails are found to follow a power-law distribution with a slope of order of sometimes -4.0 for GBP/EUR. The distribution of fluctuations in exchange rates for each 11 currency of interest is shown in Figure 3b–k. A characteristic power-law exponent of the tail of the distributions for each GBP/C_i is given in Table 1 and for each GBP/B_i is given in Table 2. The exponent is estimated for $\log(y(i+1)) - \log(y(i))$ in the range *ca.* $\sim$ [0.07,0.02]. The distribution for DEM, FRF, FIM, NLG, and ATS are close to that of the EUR, but that for BEF, IEP and ITL is wide. The FRF large rate fluctuations are similar to those of the GBP.

4 Scaling law and range of correlations in GBP exchange rate fluctuations

The DFA technique [11,14] leads to investigate whether the root-mean-square deviations of the fluctuations of an investigated signal $y(n)$ have a scaling behavior, *i.e.*

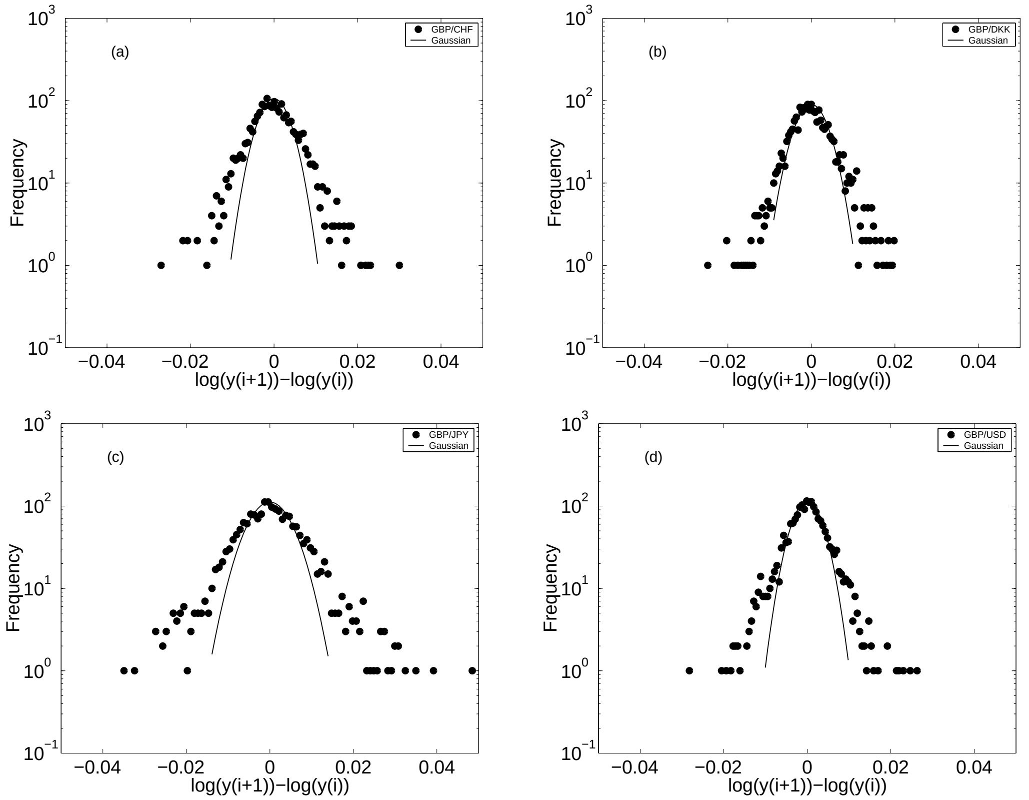

Fig. 4. Distributions of the exchange rate fluctuations for (a–d) GBP/B_i for data in Figure 2.

whether the DFA function

$$\langle F^2(\tau)\rangle = \left\langle \frac{1}{\tau}\sum_{n=k\tau+1}^{(k+1)\tau} \left[y(n)-z(n)\right]^2 \right\rangle \sim \tau^{2\alpha} \qquad (3)$$

scales with time; $z(n)$ is a linear (trend) function fitting at best the data in the τ-wide interval which is considered. A value $\alpha = 0.5$ corresponds to a signal mimicking a Brownian motion.

A log-log display of a typical DFA function leading to a measure of α for the 11 exchange rates of interest is found in the inset of Figure 5. The α-exponent values for each studied currency ExR, resulting from the analysis, displayed in Figures 5–6, are summarized in Table 1 and Table 2. The time scale invariance holds from 5 days (one week) to about 250 days (*ca.* 52 weeks or one banking year) showing a Brownian-like type of correlations.

In all cases, notice that the value of α for the EUR and other currency ExR falls very close to the Brownian motion value, – a result indicating in particular the good sense of creating and using the EUR, thus guarding against speculations like those having existed on national European currencies.

In order to probe the existence of *time dependent correlated* and *decorrelated* sequences, an observation box, *i.e.* a 514 days (two years) wide window probe is placed at the beginning of the data, calculated α for the data in that box, moved this box by one day toward the right along the signal sequence, calculated α in that box, a.s.o. up to the Nth day of the available data. A time dependent ("instantaneous") α exponent is thus found.

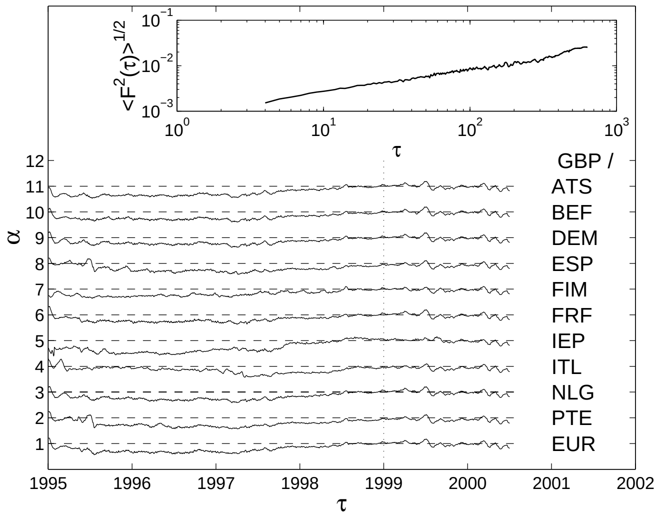

Fig. 5. Time dependence of the DFA α-exponent for GBP/EUR and each currency (which forms the EUR) exchange rate GBP/B_i. The α-values are artificially multiplied by two and then displaced along the vertical axis in order to make the fluctuations noticeable. Insert: Log-log plot of the DFA function showing how to obtain the α exponent for GBP/EUR.

The time dependent α-exponent for EUR/GBP and other currency ExR are shown in Figures 5–6, where α is determined from the best fit over the central, from 11 to 67 days (*i.e.*, from 2 to 13 weeks) box/interval maintained to be constant for any day on the examined time evolution.

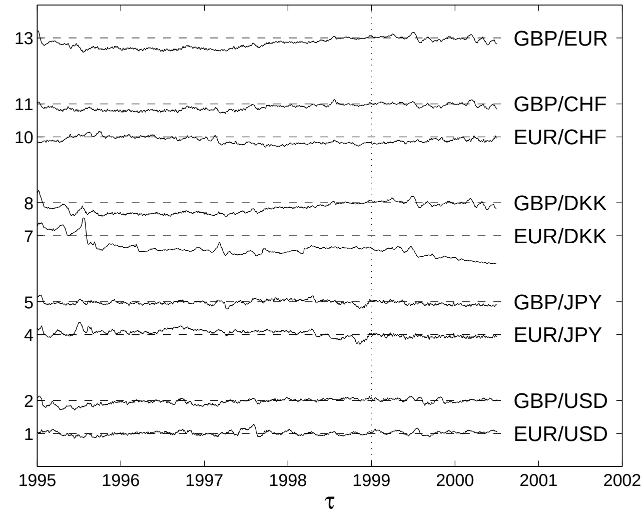

Fig. 6. Time dependence of the DFA α-exponent for GBP/EUR and for paired exchange rates GBP/B_i and EUR/B_i, where B_i are CHF, DKK, JPY and USD. The α-values are artificially multiplied by two and then displaced along the vertical axis in order to make the fluctuations noticeable.

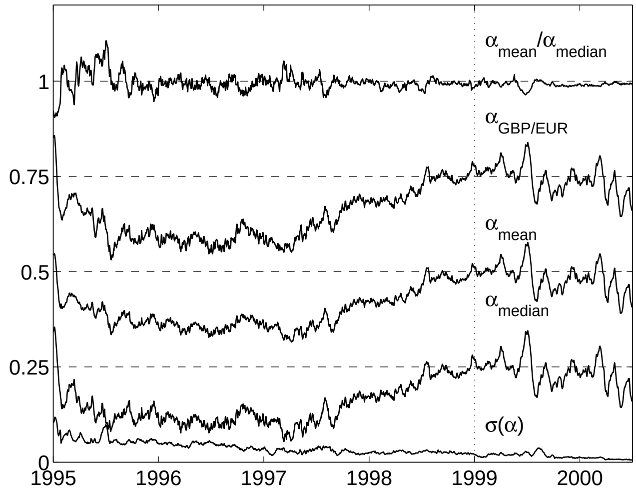

Fig. 7. Time evolution of the mean, median and standard deviation of the α exponents for the currencies forming the EUR, compared to that of EUR ExR with respect to GBP and the $\alpha_{mean}/\alpha_{median}$ ratio. The α_{mean} and $\sigma(\alpha)$ curves are not displaced. The α_{median} curve is displaced by -0.25. The $\alpha_{EUR/GBP}$ curve is displaced by $+0.25$. Horizontal dashed lines mark Brownian motion 0.5 level for each α-data.

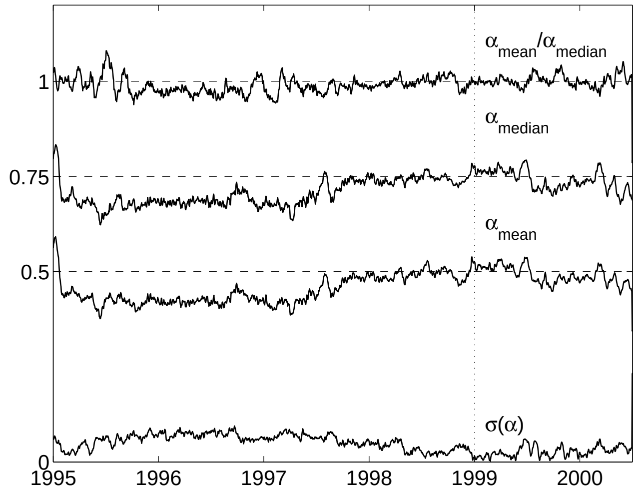

Fig. 8. Time evolution of the mean, median and standard deviation of the α exponents for GBP ExR with respect to CHF, DKK, JPY, USD and the $\alpha_{mean}/\alpha_{median}$ ratio. The α_{mean} and $\sigma(\alpha)$ curves are not displaced. The α_{median} curve is displaced by $+0.25$. Horizontal dashed lines mark Brownian motion 0.5 level for each α-data.

We stress this α evolution of paired exchange rates GBP/B_i and EUR/B_i, where B_i are CHF, DKK, JPY and USD for which results are plotted in Figure 6. From the point of view of DKK ExR, GBP and EUR are completely uncorrelated currencies, while for the USD and the JPY ExR, the GBP and the EUR fluctuate in the *same* fashion even before Jan. 1, 1999, and even more so after the introduction of the real EUR.

The evolution of fluctuation correlations in the currency ExR are very well seen (Fig. 5). Notice how different the GBP/EUR ExR behaves with respect to GBP/ITL. Interestingly the α-exponents for ESP, DEM and FRF are very close to the EUR-α-exponent behavior over the whole period, indicating the "leadership" of such currencies over the nine others. Notice the special behavior of a country currency quite tied to the UK, *i.e.* the behavior of IEP-α-exponent is markedly different from the other EUR partners.

In Figures 7–8 the time evolution of the statistical mean, median and standard deviation of the α exponents for the currencies forming the EUR and the other ones, are compared to that of the EUR in the ExR to GBP. Since the median is sometimes a better representation of the main behavior of a system, it is of interest to consider the ratio between α_{mean} and α_{median}, *i.e.* the upper curve in Figures 7–8. The mean/median ratio has large fluctuations before 1996, but clearly tends to 1 thereafter; except for some 1999 spring period, the ratio is now a constant.

5 Intercorrelations between exchange rate fluctuations

A graphical correlation matrix of the time-dependent α exponent has been constructed for the various exchange rates of interest. In Figure 9, α_{GBP/C_i} *vs.* $\alpha_{GBP/EUR}$ are shown for all i values. This so-called correlation matrix is displayed for the time interval hereby considered, *i.e.* from Jan. 01, 1995 till Dec. 31, 1998[2].

[2] The interval is so chosen because the latter has to be reduced on one hand at the lower end due to the size of the testing window box, and at the upper end by the fact that after Jan. 01, 1999 the 11 currencies are not independent any more since their conversion rates are fixed within the EUR.

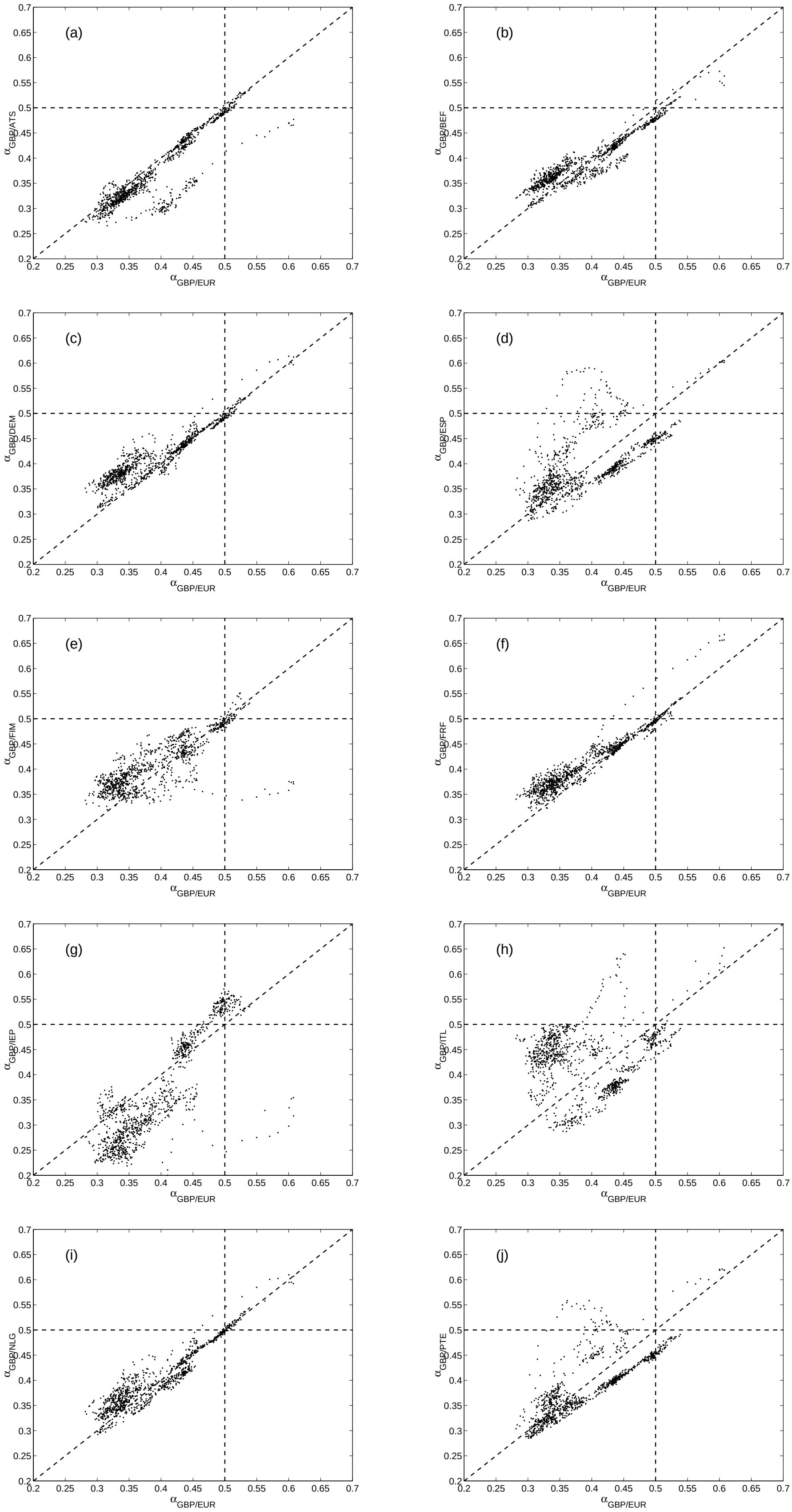

Fig. 9. Graphical representation of the so-called correlation matrix elements for the time interval Jan. 01, 1995 till Dec. 31, 1999 for the various α_{GBP/C_i} *vs.* $\alpha_{GBP/EUR}$ exponents, where C_i are the ten EUR currencies of interest ($i = 1, 10$).

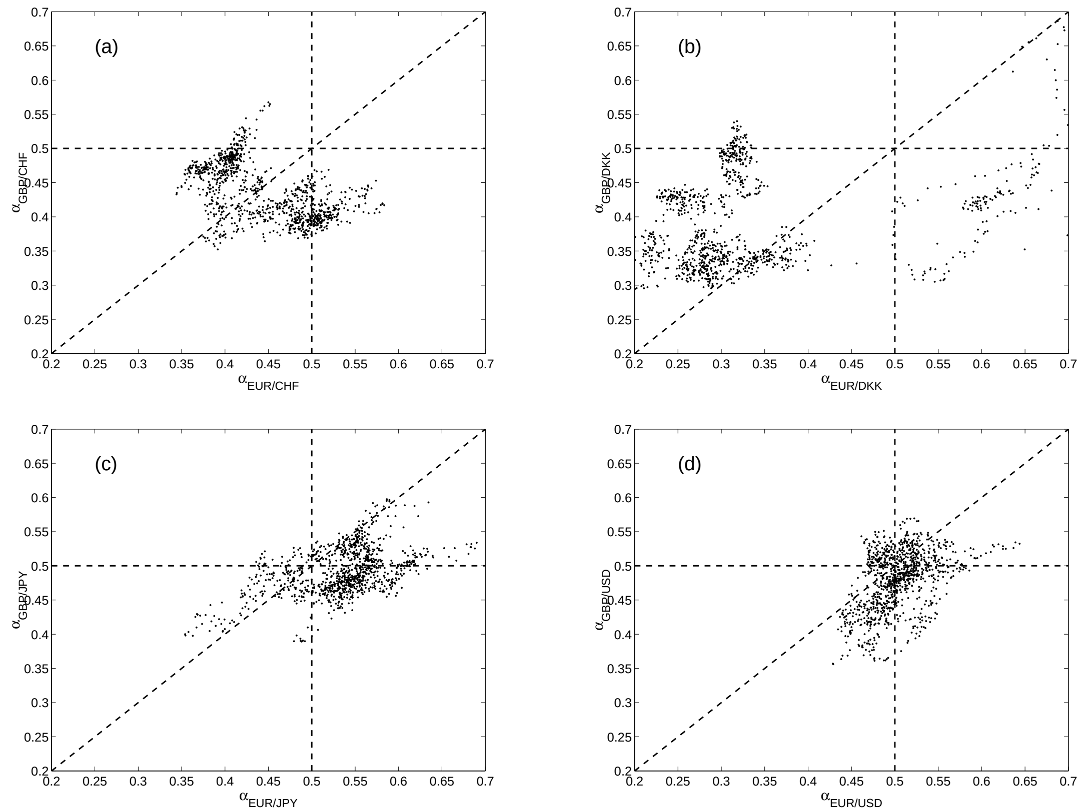

Fig. 10. Graphical representation for the time interval Jan. 01, 1995 till Dec. 31, 1999 for the various α_{GBP/B_i} *vs.* α_{EUR/B_i} exponents, where B_i are CHF, DKK, JPY and USD.

If the correlation is strong the cloud of points should fall along the slope $= +1$ line. It appears that the about equally strong correlations exist between the GBP/EUR and the GBP/DEM, GBP/EUR and GBP/FRF, GBP/EUR and GBP/BEF, GBP/EUR and GBP/NLG. Such a behavior is related to the fact that DEM and FRF are the currencies of the leading economic countries, while BEF and NLG are tightly related to both. Note that the structural diagrams for GBP/ITL, GBP/IEP, and GBP/ESP with respect to GBP/EUR show weak or no correlation at all.

The paired cross correlations of GBP/B_i are also checked using a graphical representation which is shown in Figure 10. Again the strongest (and rather similar) correlations are observed to occur between the GBP and EUR with respect to USD and JPY.

6 Conclusion

A few aspects of the EUR and its constitutive currencies exchange rates have been studied from the point of view of the fluctuations of the exchange rates toward GBP.

In examining various *reconstructed* exchange rates for the currencies forming the EUR before Jan. 01, 1999 it has been searched whether correlations would confirm historical and financial view points and so called standard knowledge. The fluctuation distribution density as examined confirms that the foreign exchange markets do not follow Gaussian distributions. The distribution of the fluctuations is close to a Gaussian one only for small fluctuations, with power-law distribution for large fluctuations. The correlation between fluctuations were close to Brownian, and the more so after the EUR was introduced. There is no doubt that speculators have not found and do not find some way to gamble on the GBP/EUR exchange rates, since the DFA-α exponent is close to 0.5. It has been noticed that the introduction of the EUR tends to smoothen the fluctuations and their correlations, as well gather together in a main stream most of the European currencies, forming the EUR.

The evolution of the correlations between the fluctuations of the paired GBP/B_i and EUR/B_i lead to a conjecture that GBP and EUR correlations from the point of view of JPY and USD evolve with time in the same manner, as if the GBP and the EUR are the same currency. However, for DKK and CHF the GBP and the EUR are different currencies.

It is clear that the leading EUR currencies from the point of view of the exchange rate fluctuations are DEM and FRF, with ITL far away from the main stream. The mean and median α evolution for GBP/EUR follows closely the mean and median α exponents for the currencies in the EUR. This is in favor of the conjecture that the GBP has already been part of the EUR system even before Jan. 1, 1999.

Thus will the EUR be a gain for Britons or not? The answer is: not more than now, on a statistical sense, since (i) GBP is already a EUR currency according to the behavior of local α; (ii) the $\alpha_{mean}/\alpha_{median}$ ratio is close to unity; (3) correlation matrix elements are close to unity as well.

What will be the future of GBP? It will surely depend on the future of EUR, and explanations, not counting hard statistical facts. According to a *Referendum Street* program, broadcasted on Sunday Feb. 18, 2001 residents of a North London borough, opposed Euro entry by 65% before hearing arguments; over the week-end, hearing both side arguments, they were in favour by 58% [20]. Pro-euro had appealed to economic arguments, while the anti-EUR side stressed the loss of sovereignty and the existence of a European super state. Our study shows that GBP is already part of EUR [4].

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References

1. M. Ausloos, K. Ivanova, Int. J. Mod. Phys. C **12**, 169 (2001).
2. M. Ausloos, K. Ivanova, *Are EUR and GBP different words for the same currency?* http://arXiv.org/abs/cond-mat/0105619, 142kb.
3. Ph. Ball, Nature, March 09, 2001, http://www.nature.com/nsu/010315/010315-1.html.
4. M. Brooks, New Scientist, Dec. 08, 10 (2001), http://www.newscientist.com/news/news.jsp?id=ns99991651.
5. R. Tomkins, The Financial Times Feb. 10/11, 7 (2001).
6. http://www.stern.nyu.edu/ nroubini/Emu/EMUGuideFT1196.htm.
7. G. Brown, The Wall Street Journal Europe, June 19, 8 (2001).
8. Ph. Hartmann, *Currency Competition and Foreign Exchange Markets. The Dollar, the Yen and the Euro* (Cambridge Univ. Press, Cambridge, 1998).
9. http://news.ft.com/ft/gx.cgi/ftc?pagename=View&c=Article&cid=FT3R5HCGXNC&live=true&tagd=ZZZU2IU.
10. R.A. Mundell, Amer. Econ. Rev. **51**, 657 (1961).
11. C.-K. Peng, S.V. Buldyrev, S. Havlin, M. Simmons, H.E. Stanley, A.L. Goldberger, Phys. Rev. E **49**, 1685 (1994).
12. C. Brooks, M.J. Hinich, J. Empir. Fin. **6**, 385 (1999).
13. E. Renault, K. Sekkat, A. Szafarz, J. Empir. Fin. **5**, 47 (1998).
14. N. Vandewalle, M. Ausloos, Physica A **246**, 454 (1997).
15. http://pacific.commerce.ubc.ca/xr/.
16. M. Ausloos, K. Ivanova, Physica A **286**, 353 (2000).
17. K. Ivanova, M. Ausloos, Eur. Phys. J. B **20**, 537 (2001).
18. K. Ivanova, M. Ausloos, in *Empirical sciences in financial fluctuations, Tokyo, Japan, Nov. 15-17, 2000 Proceedings* (Springer Verlag, Berlin, 2002), pp. 62–67, http://xxx.lanl.gov/abs/cond-mat/0103033.
19. P. Gopikrishnan, M. Meyer, L.A.N. Amaral, H.E. Stanley Eur. Phys. J. B **83**, 139 (1998).
20. E. Crooks, A. Parker, The Financial Times Feb. 17/18, 5 (2001).