Correlations Between Reconstructed EUR Exchange Rates vs. CHF, DKK, GBP, JPY and USD

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Abstract

On Jan. 1, 1999 the European Union introduced a common currency Euro (EUR), to become the legal currency in all eleven countries which form the EUR. In order to test the EUR behavior and understand various features, the EUR exchange rate is artificially extrapolated back to 1993 by a linear superposition of the exchange rates of the 11 currencies composing EUR with respect to several currencies not belonging to the EUR, i.e. Swiss Franc (CHF), Danish Kroner (DKK), British Pound (GBP), Japanese Yen (JPY) and U.S. Dollar (USD) of interest for reasons given in the text. The distribution of fluctuations of the exchange rates is shown to be Gaussian for the central part of the distribution, and having fat tails for the large size fluctuations. Within the Detrended Fluctuation Analysis (DFA) statistical method we have obtained the power law behavior describing the root-mean-square deviation of the exchange rate fluctuations as a function of time. For the period between Jan. 1995 and Jan. 1999 we have compared the time-dependent exponent of these exchange rate fluctuations for EUR and that of the 11 currencies which form the EUR. The German Mark (DEM) and the French Franc (FRF) have been the currencies primarily leading the fluctuations of the exchange rates, while Italian Lira (ITL) and (PTE) Portuguese Escudo are the less relevant currencies from this point of view. Technical considerations for the EUR implementation are given as conclusions. The cases of exchange rates with DKK appear quite different from the other four major currencies.

Keywords: Econophysics; Detrended fluctuation analysis; Foreign currency exchange rate; Euro; Scaling hypothesis
I. HISTORICAL INTRODUCTION

The theory of FExCR (foreign exchange currency rates) does not really exist or if any has been proposed it is controversial. The idea has been that FExCR fluctuations occur due to the differences in Gross National Products, - measured by national moneys. It has been proposed that FExCR fluctuations are varying as a function of the trade balance (deficit or not) between countries, - measured by international moneys. Fluctuations in FExCR surely hamper the trades because one is never sure of the FExCR variation between the order, sale, delivery and invoice time, - not counting transaction fees. Therefore, it is extremely interesting to predict the evolution of FExCR and to discover similarities between their behaviors. One technical way that 11 nations in Europe have found to reduce FExCR variations was to define a new currency EUR, based on fixed parities between these eleven European countries. How the rates were obtained and agreed upon remain a political mystery known to a few. We have already looked at the evolution of FExCR, and of the EUR in particular, even inventing a False EUR backward in time in order to observe whether previous not-so-artificial fluctuations were conserved, and whether in some sense the invention of EUR made sense from a statistical physics point of view! We have used the detrended fluctuation analysis technique (and previously a multifractal approach) to do so, a method which when applied to study the fluctuation correlations in a signal on a finite time interval in which some scaling law holds gives some information on the future evolution of the signal.

Hartmann has examined the competition between USD, JPY, and EUR. Hereby we are also trying to answer the question whether the apparently strongest currency, i.e. the DEM was/is the main basis for comparing the 11 currencies forming EUR in the past. We want to search whether there is a mathematical evidence for said to be obvious or well known historical correlations between national currencies. In order to do so we construct false exchange rates with respect to currencies like CHF, DKK, GBP, JPY, and USD. These currencies have been selected for various reasons. The CHF is a European currency from a country NOT belonging to the European Union, but usually a reference currency. The DKK and GBP are currencies for a country belonging to the European Union but not in the EUR system, with different financial and/or political views on whether or not to join EUR, and from countries having different sizes, economy, historical relevance, etc. The UK Government has decided that the UK economy is not ready for joining EUR on 1 January 1999. However, the UK Government supports the principle of joining the single currency, if that is in the national economic interest. Denmark had a referendum and raised not necessarily ad hoc arguments about DKK to becoming part of the EUR, etc. The JPY and USD are both well known major currencies outside Europe.

In the following we present a rather complete study, reporting many graphs, keeping as much as possible the same scales on axes for comparisons for several FExCR. We give the exchange rates, and their fluctuation distribution of the EUR eleven currencies and EUR itself with respect to the five selected main non-EUR currencies over the time interval Jan.01, 1993 to June 30, 2000. We perform the usual DFA and obtain the mean α exponent characterizing the power law over the longest possible scaling range pertaining to this study. We perform next the local DFA study and present in graphical form the resulting so-called correlation matrix eliminating the time as a series parameter. We summarize the data
through the mean, the variance and the median of the local $\alpha$ exponents. We conclude with some financial policy statement and historical considerations arising from our observations.

II. EXPERIMENTAL DATA

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

$$1\text{EUR} = \sum_{i=1}^{10} (\delta_i,2 + 1) \frac{\gamma_i}{11} C_i$$  \hspace{1cm} (1)

where $\gamma_i$ 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 Luxemburg Franc (LUF), with the Belgian Franc (BEF), the latter is weighted by a factor of two, whence the $\delta$ Kronecker symbol in the above equation. In order to study correlations in the EUR exchange rates, the EUR existence can be artificially extended backward, i.e., before Jan. 01, 1999 and thereby defining an artificial EUR before its birth.

The behavior of EUR with respect to currencies outside the European Union is still of interest in view of the recent fall, in particular with respect to USD, then resurgence of the EUR: considerations with respect to Swiss Franc (CHF), Danish Kroner (DKK), British Pound (GBP), Japanese Yen (JPY) and U.S. Dollar (USD) are presented below. In the following we call $B_j$, $j = 1, 5$ these 5 currencies outside the European Union, keeping $j$ as an index; the order is alphabetic in currency acronym. We have constructed a data series of EUR exchange rates with respect to these currencies following the linear superposition rule:

$$1\text{EUR}/B_j = \sum_{i=1}^{10} (\delta_i,2 + 1) \frac{\gamma_i}{11} (C_i/B_j)$$  \hspace{1cm} (2)

Since the number of data points of the exchange rates 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.

The latest date is so chosen for the present report and studies in order to remain coherent and avoid a possible spurious effect in later considerations arising from the Greek Drachma (GRD) was introduced as a supplementary currency in EUR on June 19, 2000.

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1 The greek drachma exchange rate has been locked on June 19, 2000 and the greek drachma becomes the 12th EUR equivalent currency starting on Jan. 01, 2001.
The normalized EUR exchange rates so reconstructed with respect to the CHF, DKK, GBP, JPY and USD are plotted in Fig. 1(a-e). Indicative values, for normalization purposes of the exchange rates on Oct. 2, 1996 are given in Table 1.

While the EUR/CHF and EUR/DKK exchange rate (ExR) are pretty stable and thus not much disturbed by the transition to the real EUR, the other currency ExR, in particular with respect to USD, JPY and GBP have been much sensitive to the transition, with a noticeable decay of the EUR value after Jan. 01, 1999. With respect to CHF several currencies seem to be pretty stable, as ATS, BEF, DEM, FRF, and NLG, while a neighboring country currency ITL presents a marked dip in 1995. Interestingly, with respect to DKK, FIM has a better value than all the other currencies. See again the 1995 dip of ITL, and end of 1993 bumps in ATS, BEF, DEM and NLG. The same grouping of currencies is observed for the ExR with respect to GBP, the rate evolution being rougher. For the ExR with respect to JPY and USD a wilder variation exists, with the rate being greater or smaller than unity, though with some general consistency in the evolution. The ESP, FIM, and ITL seem to be the currencies following weakly the majority (or mean for EUR) evolution.

III. DISTRIBUTION OF THE FLUCTUATIONS

The distributions of the exchange rate fluctuations for EUR/CHF, EUR/DKK, EUR/GBP, EUR/JPY, and EUR/USD are shown in Fig. 2(a-e) for the time interval of interest. The central part of each distribution, i.e. the small fluctuations, is close to a Gaussian, while the tails of the distributions, i.e. the large fluctuations, strictly depart from the normal distribution. These so-called fat tails are found to follow a power-law distribution with a slope equal to ca. 2.9 for EUR/CHF, of order of 4.0 for EUR/GBP, 3.2 for the negative and 4.0 for the positive tail of EUR/JPY, and 3.2 for the negative and about 4.5 for the positive tail in EUR/USD ExR, as found in the elastic energy price resistance - linear potential momentum trading model of Castiglione et al. Notice the asymmetry in some distributions, like the positive tail for EUR/JPY fluctuations. The distribution of fluctuations in exchange rates for each 11 currency of interest has also been studied but is not shown here for space saving. The case of the exchange rate fluctuations of the DEM with respect to DKK, CHF, JPY, and USD has already been illustrated in Ref. 12 in which the reader can observe a typical distribution as found for most of the European currencies. It is known that such tails usually have a slope markedly different from $-2$. 

IV. INTRACORRELATIONS BETWEEN FLUCTUATIONS IN A SPECIFIC EXCHANGE RATE

A. DFA results

The DFA technique has been often described and is not recalled here. It leads to investigate whether the root-mean-square deviations of the fluctuations of an investigated signal $y(n)$ have a scaling behavior, e.g. if the so-called DFA function $< F^2(\tau) >$ scales with time as
\[
\langle \frac{1}{\tau} \sum_{n=kr+1}^{(k+1)r} [y(n) - z(n)]^2 \rangle \sim \tau^{2\alpha}
\]  

(3)

where \( z(n) \) is hereby a linear function fitting at best the data in the \( \tau \)-wide interval which is considered. A value \( \alpha = 0.5 \) corresponds to a signal mimicking a Brownian motion. A thorough discussion of various features found in DFA results can be found in Ref.\(^{[13]}\) Some care must be taken concerning crossover behaviors and subliminal noise features.

A log-log display of the DFA function leading to a measure of \( \alpha \) for the 11 exchange rates of interest is found in Fig. 3 (a-e). The \( \alpha \)-exponent values are summarized with their scaling range in Table 2.

Let it be observed that the time scale invariance for EUR/CHF, EUR/JPY, and EUR/USD holds from 5 days (one week) to about 250 days (ca. 52 weeks or one banking year) showing Brownian-like type of correlations. Two different scaling ranges are found for the ATS/DKK, DEM/DKK, FIM/DKK, ITL/DKK, NLG/DKK, and EUR/DKK; one, from five to 60 days (or twelve weeks) with a non-Brownian \( \alpha < 0.5 \) and thus anti-persistent type of behavior, and another, after that for up to one year with mostly Brownian-like fluctuations within the standard error bars (see Table 2).

Notice that ITL has usually the largest \( \alpha \), even markedly greater than 0.5. An anomalous value (with respect to those quoted) is that of ATS with respect to CHF, which is interesting to view in view of the geographical proximity of the corresponding countries, thus economies. With respect to JPY and USD the correlations are similar to those in Brownian motion within the standard error bars. The case of ExR with respect to DKK is clearly different from others, with a marked double set of correlations, one anti-persistent at short time lag, and the other with a quite persistent one at longer time lag. In all cases, notice that the value of \( \alpha \) for the EUR ExR falls close to the Brownian motion value, - a result indicating the good sense of creating and using the EUR.

B. Local DFA studies

As done elsewhere,\(^2\) in order to probe the existence of locally correlated and decorrelated sequences, we have constructed an observation box, i.e. a 514 days (two years) wide window probe placed at the beginning of the data, calculated \( \alpha \) for the data in that box, moved this box by one day toward the right along the signal sequence, calculated \( \alpha \) in that box, a.s.o. up to the \( N \)-th day of the available data. A local, time dependent \( \alpha \) exponent is thus found.

The time dependent \( \alpha \)-exponent for EUR and each currency (which forms the EUR) exchange rate toward DKK, CHF, GBP, JPY, and USD are shown in Fig. 4(a-e).

For all currencies, \( \alpha \) is determined from the best fit over the central box/interval, which is maintained to be constant, for calculation ease, between 11 and 67 days (2 and 13 weeks), whence skipping the first few points from the DFA-function, known often to be deficient and also avoiding the points from the large time intervals that come with not sufficient statistics. While the differences in the \( \alpha \)-behavior after Jan. 1, 1999 are almost undistinguishable, the time dependent \( \alpha \)-exponents before that day exhibit quite different correlated fluctuations.
depending on the currency.

We stress that the evolution of fluctuations in the currency ExR are markedly seen. The behavior of the European currencies with respect to e.g. CHF is widely different from time to time and uncorrelated with each other. For the CHF ExR notice how different the EUR is, say with respect to ATS, BEF, FIM and IEP, which tend toward a EUR fluctuation behavior as time goes by. Interestingly the α-exponents for ITL and PTE are very close to the EUR-α-exponent behavior over the whole period, indicating the dependence of such currencies with respect to the nine others. The same is true for the ExR with respect to GBP, ESP, ITL and PTE forming a different group from the others. Again, 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 others. Observe the bumps in the α-exponent curve in ESP and FRF for example for the JPY exchange rate in the 1995 year, similar to the one seen in the EUR. Observe the very similar behavior of all currencies with respect to major currencies like the JPY and the USD. Finally, the α-exponents of ExR with respect to the DKK are rougher and rather different from one currency to the other, with sometimes huge fluctuations.

C. Time evolution of elementary statistical parameters

In Figs. 5 (a-d) the time evolution of the mean, median and standard deviation of the α exponents for the currencies forming the EUR, are compared to that of the EUR and DEM for CHF, GBP, JPY and USD as reference currencies. The ratio mean/median of the α exponents for the four cases is next considered.

Several remarks follow. It is clear that the leading currencies from the point of view of the exchange rate fluctuations were DEM and FRF, with PTE far away from the main stream. Larger fluctuations in the mean/median ratios are observed for CHF as reference currency in comparison to the other currencies. The largest fluctuations predominantly occur for the years before 1997. Fig. 6 allows to sort out the behavior of the fluctuations and currencies with respect to DKK. Notice that α_{mean} and α_{median} markedly evolve away from 0.5. The variation of the ratio (α_{mean}/α_{median}) in particular after Jan. 01, 1999 is due to the fact that both α_{mean} and α_{median} become small, and therefore even small discrepancies between them lead to large fluctuations of their ratio. After Jan. 01, 1999 DKK-α-values are close to that of noise-like correlations of fluctuations.

V. INTERCORRELATIONS BETWEEN FLUCTUATIONS IN EXCHANGE RATES

A graphical correlation matrix of the time-dependent α exponent has been constructed for the various exchange rates of interest. In Figs. 7 (a-e), we plot α_{C_{i}/B_{j}} vs. α_{EUR/B_{j}} for all i and j values. This so-called correlation matrix is displayed for the time interval hereby

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2Different fluctuations still exist, though with a narrower distribution, even after Jan. 01, 1999 because of the memory effect in calculating α in the DFA.
considered, i.e. from Jan. 01, 1995 till Dec. 31, 1998. 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.

As described elsewhere, e.g. in Ref. 7, such a correlation diagram can be divided into its main sectors through a horizontal, a vertical and diagonal lines crossing at (0.5,0.5). If the correlation is strong the cloud of points should fall along the slope = +1 line. It appears that the strongest correlation is that between DEM/CHF and EUR/CHF, while ATS, IEP, and PTE show weak correlations with EUR for CHF ExR as a reference currency (Fig. 7a).

The rest of the referencing currencies, i.e. GBP, JPY and USD, view DEM and FRF, and also BEF, and NLG as the leading correlated currencies in defining the EUR behavior, while the ESP, ITL and IEP seem to be outside this leading process. FIM and PTE being rather peculiar with respect to JPY. ATS joins the 'more regular ones' in the USD ExR case.

Finally, no correlation between the EUR and the 11 participating currencies exist from the point of view of DKK ExR (Fig. 7b).

VI. CONCLUSIONS

We have thus studied a few aspects of the EUR exchange rates from the point of view of the fluctuations of the EUR and the 11 currencies forming the latter. We have examined here the exchange rates toward CHF, DKK, GBP, JPY and USD.

In examining various reconstructed exchange rates for the currencies forming the EUR before Jan. 01, 1999 we have searched at 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. However the correlation between fluctuations were close to the Brownian case, and the more so after the EUR was introduced. There is no doubt that speculators have not yet found the best way to play on the EUR exchange rates, as done if the DFA-α exponent is markedly different from 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. Nevertheless it has been pointed out in the previous sections that some currencies are more tied to external ones than others due to economic and geographic-like conditions.

Several remarks follow from the correlations observed by examining the structural diagrams (Figs.7). While the structural diagrams for ATS, PTE, and ITL with respect to EUR show weak or no correlation at all, the structural diagram for DEM shows very strong correlations between the time dependent α-exponents. It is clear that the leading currencies from the point of view of the exchange rate fluctuations were DEM, FRF, together with ATS, BEF and NLG, while PTE and IEP are far away from the main stream.

It is known that the median is sometimes a better representation of the main behavior of a system, being more sensitive to the contributions from far away events. Therefore we
consider the ratio between the $\alpha_{\text{mean}}$ and the $\alpha_{\text{median}}$. This is done in Fig. 8 for the mean and median values of the $\alpha$ exponents $F_x R$ with respect to $CHF$, $GBP$, $JPY$, and $USD$. The case of $DKK$ is seen in Fig. 6. The fact that the $\alpha_{\text{mean}}/\alpha_{\text{median}}$ ratio departs from unity indicates that the distribution of $\alpha$ for $C_i/B_j$ ($j=$fixed) departs from Gaussian, for which $\alpha_{\text{mean}} = \alpha_{\text{median}}$. Therefore one may expect that the ratio $\alpha_{\text{mean}}/\alpha_{\text{median}}$ could also be used in speculation cases, and improve the way gains can be obtained.

We have observed that the $DEM$ is the strongest currency that has dominated the correlations of the fluctuations in $EUR$ exchange rates with respect to the top world leading currencies, $JPY$, $USD$, and even $GBP$ and $CHF$, while $PTE$ was the most extreme one in the other direction.

Can one gain or loose in investing in $EUR$ per se? .. is still an open question, though the behavior of fluctuations is not in favor of speculators. Is the $EUR$ a gain for humanity or not? Is the $DEM$ really the strong currency? If one had removed all currencies and established that the $DEM$ was to become the currency in the $DEM$-zone, with the Deutsche Bundesbank (BuBa) in charge of financial policy, most would have shouted loudly. In the present European policy, all central banks, including the BuBa lost control of their financial policy ... somewhat. Is that better?

A fundamental question pertains to the trend and the next one to the fluctuations in $EUR$ with respect to other moneys.

The answer is found in both cases in the behavior of $\alpha$ local, and in a previous observation by Ref. 2 that the change in $\alpha$ as a function of time is directly linked to the interest rate of the involved currencies. Thus if $\alpha$ is too far away from 0.5 it is advisable for central banks to modify the exchange rate in order to avoid gigantic speculation. Mr. A. Greenspan just did it, without knowing the local $-\alpha$ behavior theory. The same can be suggested to Mr. W. Duisenberg for the $EUR$ behavior. As long as $\alpha$ is not too far away from 0.5 (the closest is $EUR/USD$) there is no fear to have. The trend is governed by more general European economy considerations. However if it is noticed that local $-\alpha$ significantly deviates from 0.5 (the cases of $DKK$ and $GBP$) a major investigation on the $EUR$ and $DKK$ and $GBP$ rate evolution should be made. A change in interest rate should be swift if necessary. Notice that to wait a long time, as in the Plaza agreement, case is detrimental.

Floating exchange rates (and high capital mobility) presently describe the monetary regime in most countries. In the early 1960s however almost all countries were linked together by fixed exchange rates within the so-called Bretton Woods System. International capital movements were highly curtailed, in particular by extensive capital and exchange rate controls. Yet in 1961 Mundell in his article on optimum currency areas asked whether it is advantageous to relinquish monetary sovereignty in favor of a common currency? It was noticed that due to high capital mobility in the world economy, regimes with a temporarily fixed, but adjustable, exchange rate become fragile. A currency union or a floating exchange rate was proposed to be a relevant alternative, as with the common European currency. Under a fixed exchange rate, the central bank must intervene on the currency market in order to satisfy the public’s demand for foreign currency at this exchange rate. As a result, the central banks lose 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 futile because neither the interest rate nor the exchange rate could be affected. From Fig.1 it is observed that already before 1999 the separate currencies in the
then European Monetary Union were indeed fluctuating in rather similar ways.

How this was implemented is nevertheless irrelevant for our purpose: complex monetary and fiscal policy of many (sorts of) governments have been surely influencing national economic activity, and correlation between FExCR and other economic data is out of our intent but could be usefully investigated. Yet the speed of adjustment on FExCR markets and some temporarily overshoot are well seen in the various figures; they could be related to the wake of some political regional disturbances. Whether high labor mobility (supposed to be the remedy in order to offset such economic policy disturbances) was effectively intrinsic is hard to believe at this time Yet (after 1999) no supposedly strong currency was sacrificed for the EUR, and the EUR did not save any supposedly weak currency. Even though in 1996 several countries were far away from the Maastricht criteria, the EUR seems to have been an interesting vaccine.

All inventors of moneys surely thought about stability. Economic conditions showed the lure of such an ideal. New Franc, new zlotys have been invented recently, in order to avoid filling papers with a huge list of zeroes. Carolus Magnus in order to unify his Empire invented a Carolingian Pound, a piece of gold, indeed weighing half a pound. Still the Pound is used in Great Britain as a monetary unit, even though it is reduced to a light sheet of paper. In Roman time (200 BC), the coins also served to measure weight and/or buy slaves. Supposed to weigh 12 ounces (321.45 g) the Pound had a weight of only 10 ounces in order to take care for taxes and emission rights, and costs. During the years, its gold equivalent weight decreased, was made of copper, .. leather, and disappeared. What will be the future of EUR? It will surely depend on its rate in foreign exchanges.

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3It is known that some of the main advantages of a common currency rests in low transaction costs in trade and also less uncertainty about relative prices. Indeed an increased demand in one part of the currency union can cause an increased employment there which no local government bank could counteract by increasing interests rates to prevent inflation. If one feels employment is valuable, and low inflation is also valuable, then a major drawback of a currency union is that emerging local imbalances within the union cannot be counteracted only by changing interest or exchange rates for the local currency. Another of the major drawbacks is the difficulty of maintaining employment when reduction in demand for goods or more generally so-called asymmetric shocks exist. This usually requires a lowering of wages or worker lay-offs.
REFERENCES

1 Ph. Hartmann, *Currency Competition and Foreign Exchange Markets. The Dollar, the Yen and the Euro* (Cambridge Univ. Press, Cambridge, 1998).
2 N. Vandewalle and M. Ausloos, *Physica A* **246**, 454 (1997).
3 N. Vandewalle and M. Ausloos, *Eur. J. Phys. B* **4**, 257 (1998)
4 K. Ivanova and M. Ausloos, *Eur. Phys. J. B* **8**, 665 (1999); Err. 12, 613 (1999).
5 M. Ausloos, *Physica A* **285**, 48 (2000).
6 M. Ausloos and K. Ivanova, *Physica A* **286**, 353 (2000).
7 K. Ivanova and M. Ausloos, *Eur. Phys. J. B* **xx**, in press (2001).
8 T. C. Hasley, M. H. Jensen, L. P. Kadanoff, I. Procaccia and B. I. Shairman, *Phys. Rev. A* **33**, 1141 (1986).
9 [http://pacific.commerce.ubc.ca/xr/](http://pacific.commerce.ubc.ca/xr/)
10 R.N. Mantegna and H.E. Stanley, *An Introduction to Econophysics*, (Cambridge Univ. Press, Cambridge, 2000)
11 F. Castiglione, R.B. Pandey, D. Stauffer, *Physica A* **289**, 223 (2001).
12 K. Ivanova and M. Ausloos, in *Empirical sciences in financial fluctuations, Tokyo, Japan, Nov. 15-17, 2000 Proceedings* (Springer Verlag, Berlin, 2001) in press.
13 P. Gopikrishnan, M. Meyer, L.A.N. Amaral, and H.E. Stanley *Eur. Phys. J. B* **83**, 139 (1998).
14 C.-K. Peng, S.V. Buldyrev, S. Havlin, M. Simmons, H.E. Stanley and A.L. Goldberger, *Phys. Rev. E* **49**, 1685 (1994).
15 K. Hu, Z. Chen, P. Ch. Ivanov, P. Carpena, and H.E. Stanley, *private communication.*
16 R.A. Mundell, *Amer. Econ. Rev.* **51** 657 (1961).
17 [http://www.stern.nyu.edu/~nroubini/Emu/EMUGuideFT1196.htm](http://www.stern.nyu.edu/~nroubini/Emu/EMUGuideFT1196.htm)
18 [http://pacific.commerce.ubc.ca/xr/ECU.htm](http://pacific.commerce.ubc.ca/xr/ECU.htm)
Figure Captions

Figure 1 — Normalized EUR and currency forming the EUR exchange rates with respect to the (a-e) CHF, DKK, GBP, JPY and USD between Jan. 01, 1993 and June 30, 2000. The data are artificially multiplied by two and then displaced along the vertical axis in order to make the fluctuations noticeable.

Figure 2 — Distributions of the exchange rate fluctuations for (a-e) EUR/CHF, EUR/DKK, EUR/GBP, EUR/JPY, and EUR/USD for data in Fig. 1 (a-e).

Figure 3 — Log-log plot of the DFA function showing how to obtain the $\alpha$ exponent for the 11 exchange rates of interest for (a-e) EUR/CHF, EUR/DKK, EUR/GBP, EUR/JPY, and EUR/USD. The fit slope being only of interest, the DFA function data has been arbitrarily displaced along the vertical axis. The arrows indicate the best scaling ranges.

Figure 4 — Time dependence of the DFA local $\alpha$-exponent for EUR and each currency (which forms the EUR) exchange rate with respect to (a-e) DKK, CHF, GBP, JPY, and USD. The $\alpha$-values are artificially multiplied by two and then displaced along the vertical axis in order to make the fluctuations noticeable. For each time dependent $\alpha$ a horizontal dashed line is drawn to indicate a reference to Brownian fluctuations.

Figure 5 — Time evolution of the mean, median and standard deviation of the $\alpha$ exponents for the currencies forming the EUR, compared to that of the EUR and DEM for CHF, GBP, JPY and USD as reference currencies (a-d). The $\alpha_{\text{mean}}$ and $\sigma(\alpha)$ curves are not displaced. The $\alpha_{\text{median}}$ curves are displaced by -0.25. The $\alpha_{\text{EUR/}}$ curves are displaced by +0.25 and the $\alpha_{\text{DEM/}}$ curves are displaced by +0.5 in (a-d). Horizontal dashed lines mark Brownian motion 0.5 level for each $\alpha$-curve.

Figure 6 — Time evolution of the mean, median and standard deviation of the $\alpha$ exponent for the currency exchange rates with respect to DKK, currencies forming the EUR, compared to that of the EUR and DEM. The curves are displaced for readability though the y-axis scale is constant and the $\alpha_{\text{median}}$ and $\sigma(\alpha)$ curves are not displaced. The $\alpha_{\text{mean}}$ curve is displaced by +0.3. The $\alpha_{\text{EUR/DDK}}$ curve is displaced by +0.6 and the $\alpha_{\text{DEM/DDK}}$ curve is displaced by +0.9. The horizontal dashed lines mark Brownian motion 0.5 level for each $\alpha$ curve. The $\alpha_{\text{mean}}/\alpha_{\text{median}}$ ratio extracted from the $\alpha$ exponents is also shown. Horizontal dashed line at $y=2.2$ corresponds to $\alpha_{\text{mean}}/\alpha_{\text{median}} = 1$.

Figure 7 — Graphical representation of the so-called correlation matrix elements for the




time interval Jan. 01, 1995 till Dec. 31, 1999 for the various local $\alpha_{C_i/B_j}$ vs. $\alpha_{EUR/B_j}$ exponents, where $C_i$ are the ten EUR currencies of interest ($i=1,10$), and (a-e) $B_j$ are the five foreign currencies ($j=1,5$) considered in the text.

Figure 8 — Time evolution of the $\alpha_{mean}/\alpha_{median}$ ratio extracted from the $\alpha$ exponents for the currency exchange rates, currencies forming the EUR, with respect to CHF, GBP, JPY and USD. The curves are displaced for readability though the y-axis scale is constant and the GBP curve is not displaced. The horizontal dashed lines correspond to $\alpha_{mean}/\alpha_{median} = 1$. 

**TABLES**

**TABLE I.** Indicative values, for normalization purposes of all currencies exchange rates on Oct 2, 1996; e.g. 1 ATS = 0.93 USD.

| Currency | CHF | DKK | GBP | JPY | USD |
|----------|-----|-----|-----|-----|-----|
| ATS      | 0.1167 | 0.5448 | 0.0593 | 10.3913 | 0.9300 |
| BEF      | 0.0399 | 0.1861 | 0.0203 | 3.5497 | 0.0318 |
| DEM      | 0.8211 | 3.8326 | 0.4171 | 73.1140 | 0.6545 |
| ESP      | 0.0098 | 0.0456 | 0.0050 | 0.8696 | 0.0078 |
| FIM      | 0.2750 | 1.2847 | 0.1397 | 24.4880 | 0.2192 |
| FRF      | 0.2423 | 1.1327 | 0.1231 | 21.5770 | 0.1932 |
| IEP      | 2.0819 | 9.6202 | 1.0213 | 179.0200 | 1.6026 |
| ITL      | 0.0008 | 0.0039 | 0.0004 | 0.0739 | 0.0007 |
| NLG      | 0.7317 | 3.4179 | 0.3717 | 65.1580 | 0.5833 |
| PTE      | 0.0081 | 0.0380 | 0.0041 | 0.7196 | 0.0064 |
| EUR      | 1.6142 | 7.5324 | 0.8174 | 143.2853 | 1.2827 |

**TABLE II.** Numerical values of DFA-\(\alpha\) exponent for all EUR-forming currency exchange rates; the single scaling time interval is usually ca. one year, except for DKK having two distinguishable processes.

| Currency | CHF | DKK | GBP | JPY | USD |
|----------|-----|-----|-----|-----|-----|
| ATS      | 0.38 ± 0.02 | 0.22 ± 0.01 | 0.48 ± 0.04 | 0.47 ± 0.02 | 0.50 ± 0.03 | 0.51 ± 0.02 |
| BEF      | 0.45 ± 0.02 | 0.37 ± 0.03 | 0.47 ± 0.02 | 0.50 ± 0.03 | 0.49 ± 0.02 |
| DEM      | 0.50 ± 0.02 | 0.41 ± 0.03 | 0.58 ± 0.05 | 0.50 ± 0.02 | 0.51 ± 0.03 | 0.50 ± 0.02 |
| ESP      | 0.50 ± 0.02 | 0.47 ± 0.02 | 0.51 ± 0.02 | 0.51 ± 0.03 | 0.52 ± 0.02 |
| FIM      | 0.48 ± 0.02 | 0.40 ± 0.01 | 0.48 ± 0.03 | 0.46 ± 0.02 | 0.52 ± 0.03 | 0.53 ± 0.02 |
| FRF      | 0.50 ± 0.02 | 0.41 ± 0.03 | 0.47 ± 0.02 | 0.51 ± 0.03 | 0.49 ± 0.02 |
| IEP      | 0.47 ± 0.03 | 0.48 ± 0.01 | 0.41 ± 0.03 | 0.53 ± 0.02 | 0.45 ± 0.02 |
| ITL      | 0.56 ± 0.03 | 0.46 ± 0.02 | 0.60 ± 0.04 | 0.46 ± 0.02 | 0.53 ± 0.02 | 0.51 ± 0.02 |
| NLG      | 0.47 ± 0.02 | 0.32 ± 0.02 | 0.53 ± 0.05 | 0.49 ± 0.02 | 0.50 ± 0.03 | 0.50 ± 0.02 |
| PTE      | 0.41 ± 0.03 | 0.29 ± 0.02 | 0.45 ± 0.02 | 0.48 ± 0.03 | 0.48 ± 0.02 |
| EUR      | 0.51 ± 0.03 | 0.45 ± 0.02 | 0.46 ± 0.02 | 0.46 ± 0.02 | 0.52 ± 0.03 | 0.50 ± 0.02 |
FIG. 1. Normalized EUR and currency forming the EUR exchange rates with respect to the (a-c) CHF, DKK, GBP, JPY and USD between Jan. 01, 1993 and June 30, 2000. The data are artificially multiplied by two and then displaced along the vertical axis in order to make the fluctuations noticeable.
FIG. 2. Distributions of the exchange rate fluctuations for (a-e) EUR/CHF, EUR/DKK, EUR/GBP, EUR/JPY, and EUR/USD for data in Fig. 1 (a-e).
FIG. 3. Log-log plot of the DFA function showing how to obtain the $\alpha$ exponent for the 11 exchange rates of interest for (a-e) EUR/CHF, EUR/DKK, EUR/GBP, EUR/JPY, and EUR/USD. The fit slope being only of interest, the DFA function data has been arbitrarily displaced along the vertical axis. The arrows indicate the best scaling ranges.
FIG. 4. Time dependence of the DFA local $\alpha$-exponent for EUR and each currency (which forms the EUR) exchange rate with respect to (a-e) DKK, CHF, GBP, JPY, and USD. The $\alpha$-values are artificially multiplied by two and then displaced along the vertical axis in order to make the fluctuations noticeable. For each time dependent $\alpha$ a horizontal dashed line is drawn to indicate a reference to Brownian fluctuations.
FIG. 5. Time evolution of the mean, median and standard deviation of the \( \alpha \) exponents for the currencies forming the EUR, compared to that of the EUR and DEM for CHF, GBP, JPY and USD as reference currencies (a-d). The \( \alpha_{\text{mean}} \) and \( \sigma(\alpha) \) curves are not displaced. The \( \alpha_{\text{median}} \) curves are displaced by -0.25. The \( \alpha_{\text{EUR}/} \) curves are displaced by +0.25 and the \( \alpha_{\text{DEM}/} \) curves are displaced by +0.5 in (a-d). Horizontal dashed lines mark Brownian motion 0.5 level for each \( \alpha \)-curve.
FIG. 6. Time evolution of the mean, median and standard deviation of the $\alpha$ exponent for the currency exchange rates with respect to DKK, currencies forming the EUR, compared to that of the EUR and DEM. The curves are displaced for readability though the y-axis scale is constant and the $\alpha_{\text{median}}$ and $\sigma(\alpha)$ curves are not displaced. The $\alpha_{\text{mean}}$ curve is displaced by +0.3. The $\alpha_{\text{EUR/DKK}}$ curve is displaced by +0.6 and the $\alpha_{\text{DEM/DKK}}$ curve is displaced by +0.9. The horizontal dashed lines mark Brownian motion 0.5 level for each $\alpha$ curve. The $\alpha_{\text{mean}}/\alpha_{\text{median}}$ ratio extracted from the $\alpha$ exponents is also shown. Horizontal dashed line at $y=2.2$ corresponds to $\alpha_{\text{mean}}/\alpha_{\text{median}} = 1$. 
FIG. 7. Graphical representation of the so-called correlation matrix elements for the time interval Jan. 01, 1995 till Dec. 31, 1999 for the various local $\alpha_{C_i/B_j}$ vs. $\alpha_{EUR/B_j}$ exponents, where $C_i$ are the ten EUR currencies of interest ($i=1,10$), and (a-e) $B_j$ are the five foreign currencies ($j=1,5$) considered in the text.
FIG. 8. Continue Fig 7b
\( \alpha \) ATS/GBP
\( \alpha \) EUR/GBP

\( \alpha \) BEF/GBP
\( \alpha \) EUR/GBP

\( \alpha \) DEM/GBP
\( \alpha \) EUR/GBP

\( \alpha \) ESP/GBP
\( \alpha \) EUR/GBP
FIG. 9. Continue Fig 7c
\( \alpha \) ATS/JPY

\( \alpha \) EUR/JPY

\( \alpha \) BEF/JPY

\( \alpha \) DEM/JPY

\( \alpha \) ESP/JPY

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FIG. 10. Continue Fig 7d
FIG. 11. Continue Fig 7e
FIG. 12. Time evolution of the $\alpha_{\text{mean}}/\alpha_{\text{median}}$ ratio extracted from the $\alpha$ exponents for the currency exchange rates, currencies forming the EUR, with respect to CHF, GBP, JPY and USD. The curves are displaced for readability though the y-axis scale is constant and the GBP curve is not displaced. The horizontal dashed lines correspond to $\alpha_{\text{mean}}/\alpha_{\text{median}} = 1$. 