Measuring Exchange Rate Smoothness across Regimes

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I. Introduction

The issue whether or not fixed exchange rate regimes foster smoother exchange rate adjustments is still largely unresolved. The main problem in dealing with this issue is the lack of a commonly accepted framework to define and measure smoothness. Depending on the retained smoothness concept one arrives at different conclusions. If, for example, one would take variability as the standard, one finds that (semi) fixing the exchange rate decreases the variability and hence increases smoothness. However, focusing on the frequency of occurrence of extreme exchange rate changes as a measure of smoothness, one generally arrives at the opposite conclusion, see for example *Koedijk* et al. (1992).[1]

Currently, the latter concept, i. e. linking smoothness to extreme events, dominates the discussion. In a series of studies, *Koedijk* et al. (1990, 1992) argue that this approach is the relevant one. 'In some sense', they argue, 'extreme movements count the most for the economic process'. Not only do they count the most, they also lead to a distinct nomenclature; For example, in stock markets extreme shocks become crashes or market corrections and extreme exchange rate movements often get the connotation of crises. Smoothness measures then, in the view of Koedijk

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1 Note that the frequent devaluations in the EMS cannot explain this conundrum. As shown by *Koedijk* et al. (1990), if one excludes the periods of devaluations, i. e. one week before and after the devaluation, one obtains tail estimates which are only marginally different from the ones obtained when devaluations are included. It seems, therefore, that the extremities occur more often, even if the semi-fixed exchange rate system is functioning properly. Moreover, it seems highly improbable that these extremities could have been foreseen by the market. Although devaluations can be predicted fairly accurately once the speculative attack has started, it is less likely that speculators could also have foreseen the other extremities not linked to these devaluations.

et al. (1992), the frequency by which such alternative labels are given over time, or equivalently the frequency by which the market gets disturbed. Koedijk et al. (1990, 1992) use extremal value statistics to measure this frequency.

The contribution of this paper is twofold. First, it contributes to the smoothness debate by providing a complementary measure for smoothness that focuses on 'extreme events'. I thus follow the seminal idea of *Koedijk* et al. (1992) to link smoothness to the frequency of extreme events. However, unlike Koedijk et al. (1992) an explicit definition for an extreme event underlies the analysis.[2] More specifically, the researcher can –must– define what she considers an extreme event. As such smoothness rankings become more readily interpretable and can be compared under alternative definitions for extreme events.

The second contribution of this paper is empirical. Traditionally, smoothness comparisons among alternative exchange rate regimes have been made by means of ERM rates versus the Deutsche mark (DM) and the US dollar. Typically, one finds that ERM rates are less smooth in the *Koedijk* et al. (1992) sense. However, ERM rates versus the DM represent more than just ordinary examples of semi-fixed rates; The DM functions as the primary safe haven in times of crises for investors. As such smoothness rankings can be affected by this safe haven function, which although institutionalised by the ERM, is not generic for semi-fixed exchange rate regimes. In order to trace the source of the lower smoothness of DM rates, I include ERM rates versus the French franc as well. If the lower smoothness is generated by the installation of the target zone, one would expect to find equivalent results for the French franc.

The remainder of this paper is organised along the following lines. In section 2 the concept of smoothness is formalised. It is based on the frequency of extreme events. To close this definition, a definition for extreme events is provided that is general enough to encompass different distribution-free measures such as the standard deviation. Next, a distri-

[2] *Koedijk* et al. (1992) base their analysis on the limiting distribution of the maximal order statistic. Under suitable normalisation constants, they show that the probability that the maximum value crosses a certain threshold is given by the extremal distribution of type 2. However, the normalisation constants are dependent on the distribution of the exchange rate returns. By consequence, the implicit notion of an extreme event is hard to interpret. This paper, starts from an explicit definition of an extreme event that is readily interpreted and proceeds with the estimation issues. As such, the conclusions are readily interpreted. Moreover, one can easily assess the implications of using alternative definitions of extreme events.

bution-free procedure to construct a smoothness ranking is proposed. The relation between this smoothness concept, the *Koedijk* et al. (1992) and the variability measure is established by means of a simple example. Finally, the procedure developed in section 2 is applied to major semi-fixed and floating exchange rates. Results are presented in section 3. A discussion and summary of the most important findings is provided in the last section.

II. Measuring Smoothness through Extreme Events

1. *Smoothness Concepts and Measurement*

Following *Koedijk* et al. (1992), smoothness is related to the frequency of occurrence of extreme events. The lower this frequency, the smoother the random variable is. The only practical difficulty with this approach is that a proper definition of an "extreme event" is lacking. Two difficulties arise from this void. First, one must provide an accessible definition for an extreme event. Secondly, one must ensure that the occurrence of these extreme events is not marginal under this definition, otherwise the empirical relevance of the resulting smoothness ranking would be annihilated.

This section sets out a procedure to measure the smoothness of a random variable, taking the issues raised above into account. First, the statistical framework within which all statistics are derived is introduced. Given the focus on extreme behaviour, this framework sets out the assumptions on the tail behaviour of exchange rate returns. Next, two definitions formalise the smoothness concept along the route of *Koedijk* et al. (1992). Finally, the procedure to construct the smoothness rankings is explained.

Consider two random variables X_1 and X_2, each of them i.i.d., with distribution functions $F_1(X_1)$ and $F_2(X_2)$, respectively. It will be assumed, an assumption in common with *Koedijk* et al. (1992), that the distribution functions are regularly varying at infinity with tail index α_i, $i = 1, 2$, i.e.

$$(1) \qquad \lim_{x \to \infty} \frac{1 - F_1(\tau x)}{1 - F_1(x)} = \tau^{-\alpha_1}, \text{ and } \lim_{x \to \infty} \frac{1 - F_2(\tau x)}{1 - F_2(x)} = \tau^{-\alpha_2}, \tau > 0.$$

This assumption is very general and suffices for consistency of all estimators presented. Moreover, it is sufficient to construct the *Koedijk* et al. (1992) smoothness ranking. More specifically, the random variable X_1 is smoother than X_2 if and only if $\alpha_1 > \alpha_2$. The formal argument for this smoothness ranking is based on extreme value statistics;[3] It can be shown, see Koedijk et al. (1990, 1992), that for a sample of N observations:

$$\text{(2)} \qquad \Pr\left[\max_{1\leq i\leq N} \{X_i\}\, a_N < x\right] \xrightarrow{w} \exp\left(-x^{-\alpha}\right),$$

where $\xrightarrow{w}$ denotes weak convergence and a_N is a suitable normalising constant, dependent on the distribution of X. Intuitively, the tail index ranks the random variables according to the probability of observing an (extreme) event, i.e. Xa_N larger than a prespecified value x. This probability decreases with the tail index α. However, the distribution dependent constant a_N impedes a direct interpretation of the smoothness ranking since distributions can differ across random variables.

In order to circumvent the problem of the unknown constant α_N, an alternative procedure based on the *Dekkers* and *de Haan* (1989) Statistic can be used. This procedure, however, requires more detailed information concerning extreme events. Definition 1 presents the definition of an extreme event. Consequently, definition 2 relates the concept for smoothness to this definition of an extreme event.

Definition 1 An event $X > E$ is called an extreme event under the measure S_l and with probability $p \ll 1$, if and only if $\Pr[X/S_l \leq E] = 1 - p$.

Definition 1 states that an extreme event is defined by a certain (prespecified) probability of occurrence. More specifically, by fixing the probability of an extreme event, p, the lower bound for a realisation to be called an extreme event is given by E. Implicitly, the definition is restricted to positive extreme events, by imposing $p \ll 1$. However, negative extreme events can be defined analogously. The measure S_l allows to analyse different types of smoothness concepts. For instance, one could analyse exchange rate innovations directly, i.e. $S_l = 1$, or alternatively use standardised returns, i.e. $S_l = \sigma_X$, with σ_X the standard deviation of X. Note that S_l can be modified to the user's need as long as it is a distribution free measure.

Definition 2 The random variable X_1 is smoother than X_2 under measure S_l and probability p if $E_1 < E_2$.

3 For an accessible treatment of extremal value statistics and their limiting distribution see for instance *Mood* et al. (1974), pp. 258 - 263.

In definition 2, the smoothness concept is defined. A series is called smoother if the lower bound for an extreme event with probability p is lower. This is of course equivalent to stating that the probability that X_1 is larger than E_2 is smaller than the probability for $X_2 > E_2$.

The reason to state the smoothness rankings in terms of lower boundary conditions E_i, is that these thresholds are readily estimated using the *Dekkers* and *de Haan* (1989) statistic. Moreover, the values for E_i can be estimated without the need to specify the exact distribution of the series under analysis. All that is required is the assumption of regular variation at infinity.

Using this assumption, a distribution free estimator for the $(1 - p)$-th quantile can be constructed even if this quantile exceeds the sample length. Define the order statistics of the sample $\{X_{j,i}\}_{i=1}^{N}$ by $\left\{X_{j,(i)}\right\}_{i=1}^{N}$ with $X_{j,(1)} \leq X_{j,(2)} \leq \ldots \leq X_{j,(N)}$. Using the results of *Jansen* and *de Vries* (1991) and *Dekkers* and *de Haan* (1989), the estimator for E_j under measure S_l and $p \ll 1$ is given by:

$$
(3) \quad
\begin{aligned}
&(i) \qquad \hat{E}_j = \left[\frac{\left(\frac{M}{2pN}\right)^{\hat{\gamma}} - 1}{1 - 2^{-\hat{\gamma}}}\right] \left(Y_{j,(N - M/2)} - Y_{j,(N - M)}\right) + Y_{j,(N - M/2)} \\
&(ii) \qquad Y_{j,(i)} = \frac{X_{j,(i)}}{S_l} \\
&(iii) \qquad \hat{\gamma} = \frac{1}{M} \sum_{j=1}^{M} \ln\left(\frac{X_{j,(N + 1 - i)}}{X_{j,(N - M)}}\right),
\end{aligned}
$$

with $3(iii)$ the *Hill* (1975) estimator based on M order statistics. The tail index, used by *Koedijk* et al. (1992), is usually estimated by the reciprocal of the Hill estimator. Note that as long as the measure S_l is distribution-free, as for example in the case of the moments, such as the standard deviation, the estimator for E is distribution free. In other words, the above procedure allows to compare smoothness across exchange rate regimes, even if they are characterised by different unconditional distribution functions.[4] A heuristic interpretation of this estimator is provided by *Jansen* and *de Vries* (1991).

[4] Note that the distribution dependent issues are taken care of by the order statistics explicitly entering the estimator for the threshold values E.

2. An Example

In order to illustrate the concepts introduced in the section II.1, consider the following example[5]. Suppose one wants to compare the smoothness of two random variables. Each random variable, X_1 and X_2, is distributed as a Student-t distributed with degrees of freedom, $\nu_1 > \nu_2$, and strongly different variances, $s_1 \frac{\nu_1}{\nu_1 - 2} \equiv E(X_1^2) \gg E(X_2^2) \equiv s_2 \frac{\nu_2}{\nu_2 - 2}$, $s_1 > s_2$. According to the variance measure, variable 2 is smoother than variable 1, while in the *Koedijk* et al. (1992) analysis the opposite conclusion emerges.[6] The main contribution of the newly introduced concept of smoothness is that it is relativistic and obliges the researcher to be very explicit about the definition of an extreme event. More specifically, one needs to specify the probability and the measure precisely.

According to definition 2, taking $S_l = 1$, X_1 is smoother (less or equally smooth) than X_2 if $\sqrt{s_1}F^{-1}(1 - p; \nu_1) < (\geq) \sqrt{s_2}F^{-1}(1 - p; \nu_2)$, or equivalently $\sqrt{s_1}/\sqrt{s_2} < (\geq) F^{-1}(1 - p; \nu_2)/F^{-1}(1 - p; \nu_1)$, with F the standardised t-distribution. Suppose, for instance, that $\sqrt{s_1}/\sqrt{s_2} = 3$, $\nu_1 = 3$ and $\nu_2 = 10$. The smoothness measure in definition 2 would agree with the *Koedijk* et al. (1992) conclusion only if $p < 0.0005$. Otherwise, i.e. $p > 0.0005$, one would contradict the *Koedijk* et al. (1992) conclusion. Which one is the more relevant ranking is in general subjective. However, if one follows the *Koedijk* et al. (1992) ranking one implicitly bases this ranking on events that are marginal. Indeed, the probability of observing an extreme events that justify this ranking after N observations on the random variables equals $(1 - p)^N$. For instance, after 520 observations, the probability of not observing an extreme event is 77 %. So in this example, the *Koedijk* et al. (1992) ranking might be of only marginal practical importance. Alternatively, suppose that $\sqrt{s_1}/\sqrt{s_2} = 1.05$, then agreeing with the smoothness conclusion based on the variance implies that the p value is larger than 0.25. This probability is rather large to use in definition 1 as a means to identify extreme events. Hence,

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5 The example is constructed such that the variance is higher for the series with the higher degrees of freedom. Therefore, by construction, the rankings will differ. However, this example is a stylised representation of the smoothness results obtained in the literature. Typically, free floating rates have higher degrees of freedom and at the same time larger variance than their semi-fixed counterparts. Note, however, that the numbers used in the example bear no resemblance to the results in any of the listed papers.

6 It can be shown that the tail index equals the degrees of freedom of the Student-t distribution (see *Koedijk* et al. (1990))

the smoothness ranking cannot fully account for the different behaviour of extremities across random variables.

One could also use a relative smoothness concept. For example, setting $S_l = \sigma_{X_j}$, would yield the same conclusions for all three smoothness rankings: random variable 1 is the smoother one. This congruence in smoothness rankings is however due to the assumption that all distributions are Student-t distributions. It is easily seen that smoothness rankings can differ as well for this relative ranking if distribution functions differ.

In short, the above example convincingly demonstrates that smoothness orderings cannot be stated without reference to the definition of an extreme event and more particularly the p value. Making this value explicit avoids the implicit problem that the orderings based on the tail index might be too restrictive, say an extreme event occurring only 5 times out of 10000 trials, rendering the conclusion irrelevant for practical purposes. Also, too permissive definitions can be avoided.

To summarise this section, a new definition of smoothness was proposed. This smoothness measure has the advantage that it makes explicit what is considered an extreme event. More specifically, one needs to specify the measure S and more importantly the probability of observing an extreme event, p. The section then proceeded with the introduction of a distribution-free estimator for the cut-off values E. Basically, the E values are defined by the $(1 - p)$-th quantile. For small p values, such an estimate is not obtainable by standard quantile estimators as the sample is simply too short. In the next section the smoothness characteristics of alternative exchange rate regimes are analysed in greater detail.

III. Smoothness of Alternative Exchange Rate Regimes

Two facts concerning the behaviour of exchange rate movements across regimes are currently undisputed. First, semi-fixed exchange rate regimes display smaller volatility of exchange rate returns. At the same time they have the lower tail statistics, see *Koedijk* et al. (1990, 1992). If smoothness is defined as variability, then clearly one would conclude that semi-fixed exchange rate regimes increase smoothness. However, it is by now generally accepted that smoothness cannot be defined by variability. Instead, smoothness refers to the frequency of extreme events. This definition is, however, not self-contained since one needs to supply a definition of an extreme event.

In this paper, such a definition is provided. Two values must be supplied, the probability p and the measure S_l used as a basis of comparison. In this section, I fix the p to 0.005. This implies that, since the frequency of the sample is weekly, the probability of not observing an extreme event in 1, 2 and 3 years is 0.77, 0.59 and 0.46. The conclusions are therefore based on events that have a nontrivial probability of occurring. As such, conclusions have a practical value.

With respect to the measure S_l two approaches are taken. First, a relative viewpoint is taken by using $S_l = \sigma_{x_j}$. As such, an extreme event is defined as an event that is more than E times the expected size of the exchange rate movement, where E is fixed by the p value. Free floating rates may thus be smoother than semi-fixed exchange rates if the minimal size of the 5% largest exchange rate movements is closer to the unconditionally expected size of the change than in the case of semi-fixed exchange rates.

A second point of view defies this relativistic viewpoint. It states that there is one and the same expected size of exchange rate changes across exchange rate regimes. For simplicity this one is fixed to 1. However, any nonzero, positive and finite alternative yields the same conclusions concerning smoothness. This viewpoint is thus absolute. It takes a normative point of view, namely that exchange rate changes should not exceed a fixed quantity.

Unless one restricts the distribution functions to be of the same class, both viewpoints on smoothness depend both on the variability and the tail index.[7] Therefore, one cannot select one of them in function of the measure used to order the series according to smoothness. In order to rank the series accordingly one needs to estimate the E values by means of equation 3.

The data set to which this smoothness measure will be applied consists of 17 exchange rate series. More specifically, it contains the Belgian franc, Dutch guilder, Danish krone, French franc, Irish pound and Italian lire quoted against the Deutsche mark and French franc respectively. The six series for the floating exchange rates consist of all possible exchange rates for the yen, the British pound and US dollar quoted against the Deutsche mark. The sample starts with the inception of the EMS and ends with the crisis in 1992. The data are obtained from

[7] *Boothe* and *Glassman* (1987) show that even within the class of free floating exchange rates unconditional distribution functions differ. They differ not only in the parameters such as scale and mean but also in functional form.

Datastream and are sampled at the weekly frequency. This yields 704 weekly returns.

In order to account for the possible asymmetric nature of the EMS, I calculate the various smoothness measures at both ends of the distribution function. More in particular, the lower and upper tail index are computed to analyse the smoothness ordering according to *Koedijk* et al. (1992). Moreover I also compute the E values under the measures described above at both sides of the median. More specifically, I compute the p-th and the $(1 - p)$-th quantile, using the estimator proposed in (3). Results for the right tail of the distribution are listed in tables 1 and 3, those for the left side in tables 2 and 4.

The use of an absolute measure, $S_l = 1$, does not yield new insights. In general, semi-fixed exchange rates are smoother in this measure, basically because they limit the variability of exchange rate movements. This conclusion is in line with the conclusions available in the literature regarding the volatility effects of target zones, see for example *Artis* and *Taylor* (1988).

However, the results for the relative measure are more informative. The implied smoothness orderings are visualised in Figures 1 to 5. Figures 1 and 2 provide the smoothness ordering based on the *Koedijk* et al. (1992) ordering for the right and left tail, respectively. The higher the tail index the smoother the exchange rate is in the Koedijk et al. (1992) sense. Two conclusions emerge. First, for both figures, floating exchange rates are smoother than semi-fixed exchange rates. Secondly, the ordering between ERM exchange rate quoted against the DM and FF differs across tails. For the right tail, one finds that the DM rates are smoother, while the opposite conclusion holds for the left tail. This implies that extreme positive (i.e. depreciation of DM and FF) shocks are less likely for the DM rates than for the FF rates. Extreme appreciation is more likely in the case of the DM rates.

The smoothness orderings, according to the procedure set out in section 2 (using the relative version, i.e. $S_l = \sigma_x$), are depicted in figures 3 and 4. Here, the higher the (absolute) E value the less smooth the series is. A different conclusion emerges. For the right tail, it is difficult to classify the ordering according to exchange rate regime. Typically, positions interchange from regime along the path. The left tail, however, provides a clearer picture. The DM rates of the ERM currencies tend to be the least smooth. The floating rates take an intermediate position and the smoothest exchange rates are the ERM rates versus the French franc.

Table 1

Smoothness Measures on Righthand Side of Distribution: ERM Currencies (1979 - 1992)

	Tail Index	E-value (ABS)	E-value (REL)
BF/DM	2.32 [1.58 - 3.05]	0.021	3.82
DG/DM	2.04 [1.39 - 2.69]	0.009	4.11
DK/DM	2.56 [1.74 - 3.37]	0.012	2.76
FF/DM	2.93 [1.99 - 3.85]	0.007	1.40
IP/DM	2.72 [1.72 - 3.32]	0.010	2.12
IL/DM	2.52 [1.72 - 3.33]	0.013	2.18
BF/FF	2.01 [1.37 - 2.65]	0.027	4.21
DG/FF	1.83 [1.24 - 2.41]	0.014	2.93
DK/FF	2.28 [1.56 - 3.01]	0.011	2.11
IP/FF	2.17 [1.48 - 2.86]	0.019	3.59
IL/FF	2.07 [1.41 - 2.73]	0.018	3.19

Notes: Tail index is measured by the *Hill* estimator with 38 order statistics. Numbers within brackets give the 95 percent confidence interval. The E values are computed by means of equation (3). E (ABS) refers to the case where the measure $S = 1$. E (REL) gives the E values when the S measure equals the standard deviation. Currency acronyms are as follows. BF: Belgian franc, DG: Dutch guilder, DK: Danish krone, FF: French franc, IP: Irish pound and IL: Italian lire. x/y denotes the number of currency y to be paid for one unit of x. Since the table looks at the right tail it is concentrated on the characteristics when the FF and DM depreciate and/or devaluate against the other retained currencies.

Finally, figure 5 presents the maximal E value across both sides of the tails. This measure can therefore be interpreted as a global smoothness measure. Again, the conclusion is that ERM exchange rates versus the DM are the least smooth, floating rates take an intermediate position and finally, the ERM rates recorded against the French Franc are smoothest.

Table 2

Smoothness Measures on Lefthand Side of Distribution: ERM Currencies (1979 - 1992)

	Tail Index	E-value (ABS)	E-value (REL)
BF/DM	2.44 [1.67 - 3.21]	−0.018	−3.25
DG/DM	1.90 [1.29 - 2.50]	−0.014	−5.87
DK/DM	1.69 [1.15 - 2.23]	−0.020	−4.67
FF/DM	1.59 [1.08 - 2.09]	−0.023	−5.06
IP/DM	1.88 [1.28 - 2.48]	−0.020	−4.09
IL/DM	1.72 [1.17 - 2.27]	−0.044	−7.36
BF/FF	2.23 [1.52 - 2.93]	−0.023	−3.52
DG/FF	3.37 [2.29 - 4.44]	−0.010	−2.09
DK/FF	2.33 [1.59 - 3.07]	−0.015	−2.79
IP/FF	2.35 [1.60 - 3.10]	−0.016	−3.05
IL/FF	1.87 [1.27 - 2.45]	−0.021	−3.63

Notes: Tail index is measured by the *Hill* estimator with 38 order statistics. Numbers within brackets give the 95 percent confidence interval. The E values are computed by means of equation (3). E (ABS) refers to the case where the measure $S = 1$. E (REL) gives the E values when the S measure equals the standard deviation. Currency acronyms are as follows. BF: Belgian franc, DG: Dutch guilder, DK: Danish krone, FF: French franc, IP: Irish pound and IL: Italian lire. x/y denotes the number of currency y to be paid for one unit of x. Since the table looks at the left tail it is concentrated on the characteristics when the FF and DM appreciate and/or revaluate against the other retained currencies.

This conclusion seems at odds with the conclusion based on the tail indices. Eventually, as $p \to 0$, there must be a cut-off point where the ordering based on the E-values converges to the one of the tail indices. However, the main difference between my approach and the one of the tail index lies exactly in this p value. I experimented with alternative

Table 3

Smoothness Measures for Righthand Side of Distribution: Free Floating Rates (1979 - 1992)

	Tail	*E*-value (ABS)	*E*-value (REL)
DOL/DM	4.29 [2.92 - 5.64]	0.039	2.52
P/DM	3.73 [2.55 - 4.92]	0.053	2.45
P/DOL	3.37 [2.30 - 4.43]	0.058	3.79
Y/DM	3.36 [2.29 - 4.43]	0.078	3.60
Y/DOL	3.59 [2.45 - 4.73]	0.038	2.47
Y/P	3.92 [2.67 - 5.16]	0.073	3.28

Notes: Currency acronyms: DOL: US dollar, DM Deutsche mark, Y: yen and P: British pound. See also notes in Table 1.

Table 4

Smoothness Measures for Lefthand Side of Distribution: Free Floating Rates (1979 - 1992)

	Tail	*E*-value (ABS)	*E*-value (REL)
DOL/DM	3.76 [2.57 - 4.96]	−0.051	−3.30
P/DM	3.37 [2.29 - 4.43]	−0.074	−3.45
P/DOL	2.83 [1.93 - 3.74]	−0.062	−4.05
Y/DM	3.26 [2.22 - 4.29]	−0.084	−3.88
Y/DOL	4.03 [2.75 - 5.32]	−0.054	−3.49
Y/P	3.55 [2.42 - 4.69]	−0.071	−3.21

Notes: Currency acronyms: DOL: US dollar, DM Deutsche mark, Y: yen and P: British pound. See also notes in Table 2.

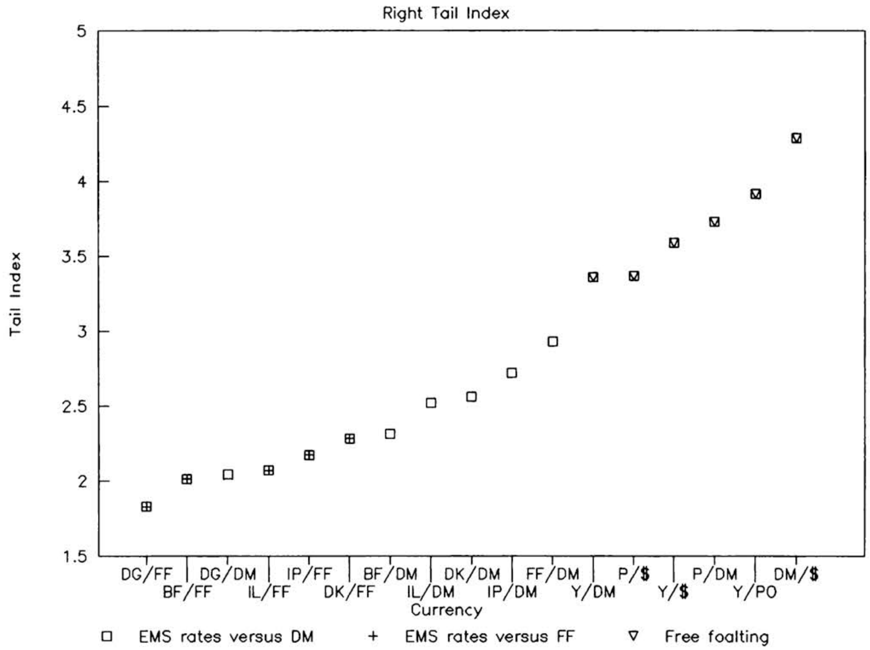

Figure 1: Smoothness Ordering

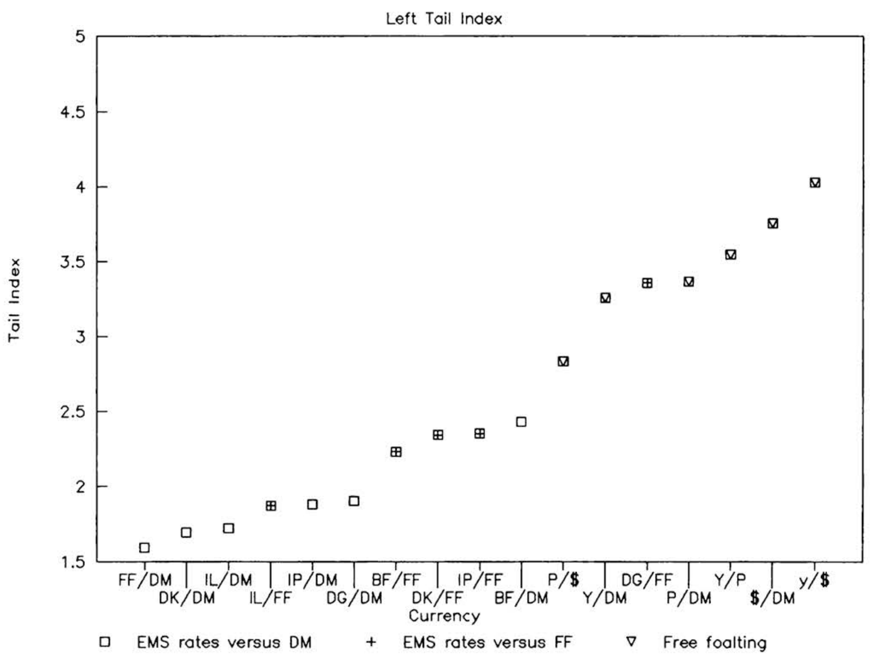

Figure 2: Smoothness Ordering

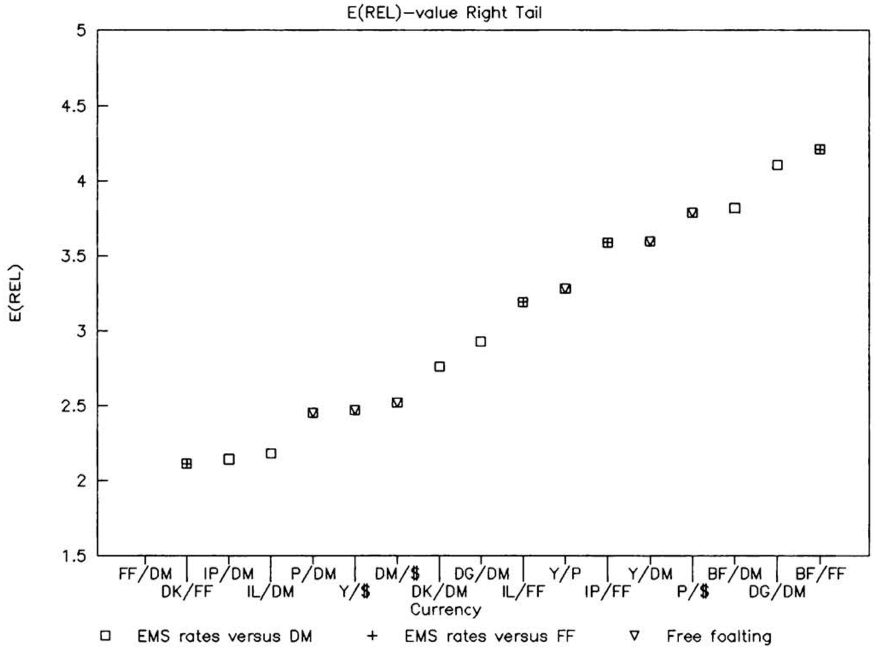

Figure 3: Smoothness Ordering

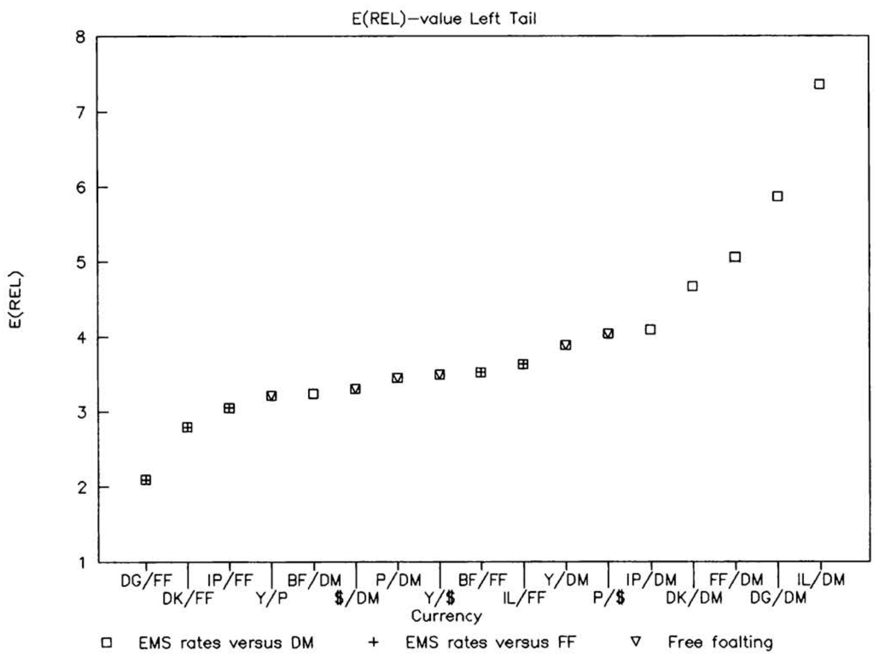

Figure 4: Smoothness Ordering

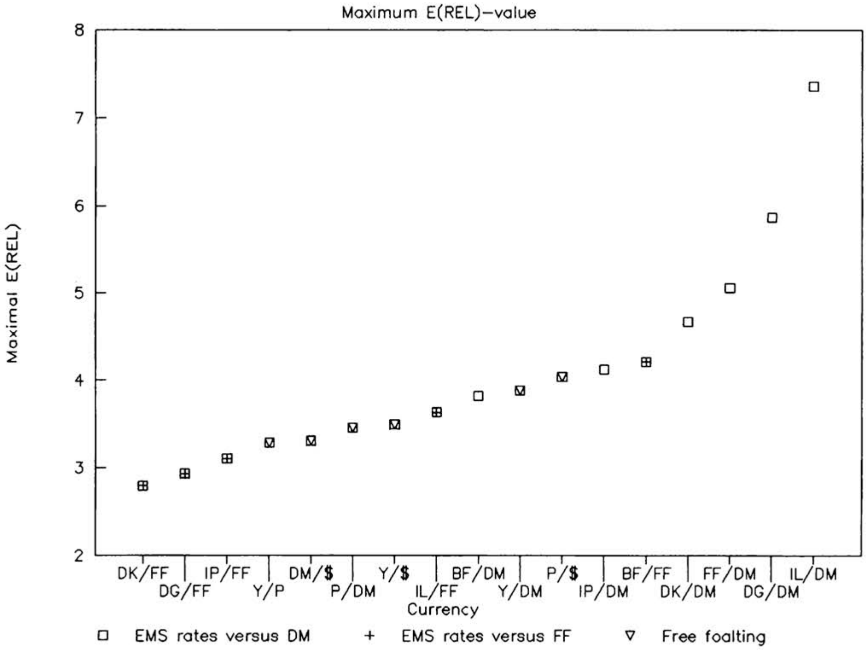

Figure 5: Smoothness Ordering

lower values for *p*. The conclusions were unaltered even for p values as low as 0.00001. So, even if the definition of an extreme event changed to this type of p values one would still not converge to the tail index ordering. Therefore, one might question the practical relevance of the tail index ordering. From a practitioner's point of view the ordering based on the E-values seems more appropriate.

The above analysis thus leads to the conclusion that, according to the computed smoothness measures, the distinction between semi-fixed and floating exchange rates is not as clear-cut as often suggested by the *Koedijk* et al. (1992) procedure. Once one starts to measure cross-rates in the ERM, as for instance against the French franc, one can no longer justify the claim that semi-fixed exchange rate regimes increase the frequency of extreme returns. The causes of these differences can of course not be identified by a descriptive statistic, such as the one introduced in this paper, one can only speculate. One, potential explanation might be the asymmetric role the anchor currency obtains in a semi-fixed exchange rate system. Often, such a currency is used as a safe haven in times of turbulence. One may suspect that such a role increases the likelihood of extreme movements against other currencies as investors flee into that currency and not to that of another noncentral currency. However, unless more direct research is pursued in this direction, the presented reasoning remains speculative.

IV. Discussion

In this paper the issue of smoothness across exchange rate regimes was addressed. Many studies have compared the performance with respect to smoothness and the results critically depend on how smoothness is defined.

A self-contained procedure was presented to estimate the smoothness of exchange rates across regimes. This procedure requires the researcher to be very explicit about what he/she considers to be an extreme event. This information requirement prevents the fallacy that conclusions may be based on too permissive or too stringent definitions of extremities. The critical parameter in this procedure is the threshold level that defines an extreme event. These threshold levels, as shown in this paper can easily be estimated by means of the *Dekkers* and *de Haan* (1989) statistic.

As an illustration of the methodology, the smoothness of exchange rate regimes was analysed using a definition of extreme events based on the standard deviation and on an absolute standard. What the results show is that smoothness is not necessarily one to one with the exchange rate regime. Typically, ERM rates against the DM are the least smooth. However, ERM rates versus the French franc were found smoother than floating rates. This suggests that smoothness of exchange rate changes is not fully explained by exchange rate regimes. One possible direction for future research is to assess the links between the asymmetries in the functioning of semi-fixed exchange rate regimes and the frequency of extremities.

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Summary

Measuring Exchange Rate Smoothness across Regimes

This paper proposes a framework to analyse the smoothness of exchange rates across regimes and applies this framework to the ERM rates both quoted against the Deutsche mark and the French franc. It is found that the traditional conclusion that semi-fixed exchange rate regimes decrease the smoothness crucially depends on whether one analyses Deutsche mark rates or French franc rates.

Zusammenfassung

Messung der regimeübergreifenden Geschmeidigkeit von Wechselkursen

Dieser Beitrag schlägt einen Rahmen vor für die Untersuchung der regimeübergreifenden Geschmeidigkeit von Wechselkursen und wendet diesen Rahmen an auf die in Deutscher Mark und französischen Francs notierten Kurse des Europäischen Wechselkursmechanismus. Es wird festgestellt, daß die traditionelle Schlußfolgerung, daß Systeme mit quasi-festen Wechselkursen die Geschmeidigkeit mindern, entscheidend davon abhängt, ob in Deutscher Mark oder in französischen Francs notierte Kurse untersucht werden.

Résumé

La mesure de l'équivalence des taux de change selon les régimes

Cet article propose un modèle d'analyse de l'équivalence des taux de change suivant les régimes et applique ce modèle aux taux du ERM, cotés par rapport au Deutsche Mark et au Franc français. La conclusion traditionnelle que les régimes de taux de change semi-fixe diminuent l'équivalence, dépend principalement des taux de la référence, Deutsche Mark ou Franc français, utilisés pour l'analyse.