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THE LIBOR RATE: WHAT DOES IT LOOK LIKE DURING TURMOIL TIMES?

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Abstract

The aim of this paper is to study the dynamics of the interbank rates during the turmoil times. The reference we used is the Libor rate (1 and 3 months maturities), an essential benchmark for many contracts notably the CDS and derivative products. To achieve our goal, we used various types of econometric tests. After checking the non-stationarity versus the non linearity, we adopted four methodologies to test the presence of unit root tests versus breaks. Our main findings are, for the principal currencies Libor references (Us, Euro), that they are actually stationary with breaks. It confirms so the bias of classical tests, already stated by Perron 1989.

Keywords: Libor, unit root with breaks.

JEL Classifications: C12, C13, C22.

Introduction

To describe the dynamics of the interbank rates market is particularly challenging, especially in the recent period where banks are heavily charged to manipulate interest rates. Actually, at the end of June, British and US banking authorities found evidence that Barclays' senior management and multiple traders tried to fix artificially key borrowing rates (London Interbank Offered Rate and Euribor) for years. Traders at the bank – but other institutions might be concerned- seem to have engaged in regular attempts to determine the Libor from as early as 2005.

An interbank rate is the rate of interest paid on a loan from one private or public bank to another (excluding central bank). The functioning of interbank money markets was severely impaired after the second half of 2007 according to different studies including those from BBA and the situation seems not to have reached a normal pattern yet. Uncertainty about losses associated with US subprime mortgage-related structured products led large banks to revise upwards their liquidity needs while making them also more reluctant to lend to each other, in particular at longer maturities, due to a lack of confidence to each other. Financing for terms of

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more than a few days was reportedly not readily available at the most commonly referenced interest rate, the London interbank offered rate (Libor).

Indeed, the Libor rate is a reference for many types of interbank credits and then for bonds and household credits. Although quoted in London, it is defined in various currencies. The rate in US dollar is of great importance for the US banks as an indicator for the liquidity situation in the whole American banking sector. Considering this predominant role in the economy, it is necessary for the financial markets participants to measure its statistical properties. It is for example interesting to observe a possible mean-reverting process driving its dynamics, allowing for possible forecast.

This notion of mean-reverting process is bound with the notion of time series (weak) stationarity in the sense that a series fluctuate around a constant in the long run (mean) and that the finite variance does not depend upon time. The conclusions are opposite for non- stationary series: a shock has lasting and even infinite consequences on the dynamics of the variable and there is no return to equilibrium. An econometric study is then compulsory to discriminate between these alternative assumptions.

In the literature, the conclusions are ambiguous: some econometric time series papers treat interest rates as non-stationary integrated processes (Rose, 1988, Rapach & Weber, 2004), however theoretical models of continuous time finance generally imply stationary interest rates. Possible non-stationarity might result from severe shocks which affect the economy. It is consequently interesting to detect significant break(s) and study the pattern of the time series before and after this or those breaks. Moreover, the results of the classical unit roots tests are severely affected by the existence of turning points in the series since those tests allow only a continuous deterministic linear trend. Perron (1989) proved that the DF tests are biased in favor of the unit root null hypothesis.

We found so relevant, taking into account the previous considerations, to see if the Libor pattern was stationary or not and featured by break(s). To that purpose, we used different tests to check the robustness of our conclusions. Our data sample, limited to the US dollar, the GB pound and the Euro rates, spreads the period January 2005-September 2011. This period was affected by different significant economic events, notably subprime crisis with its consequences like Lehman Brothers collapse and Greek debt financing crisis. It led to a dryness of the liquidity of major interbank markets which raises questions about the reliability of rate fixings supposed to represent conditions in these markets.

Due to the difficulty to impose a priori a date for the ruptures, we set up tests which determine endogenously break dates. We began firstly with the most classical Zivot and Andrews (1992) test, followed by that of Perron (1997).We authorized then multiple break models since there is no reason to impose only a unique break in the last period marked by many economic turbulences. Our approach consists in using the procedures adopted by Lumsdaine and Pappel (1997) and Kapetanios (2005).

Our study contributes firstly to the debate around the controversial Libor. This rate has actually been questioned, in its determination and its normal level during the period under review, by practitioners and academics as well (Gyntelberg and Wooldridge 2008, Mackenzie and Tett 2008). It contributes secondly to the question of interest rate stationarity versus the presence of breaks. From an empirical point of view, we used a large span of available methods to strengthen our results. They are globally in favor of interest rate stationarity with a break. The date is around the 8th October 2008 featured by a large decrease in the equity market.

The paper is organized as follows. The first section is dedicated to the economics of Libor, the second is an overview of literature of unit root tests with breaks and the third is the presentation of data and results.

The Economics of Libor Rates

The Libor market is a well-known reference for interbank money market conditions. Published daily by the British Bankers' Association (BBA), it applies for a wide range of currencies and maturities. By the late 1980s, the three-month Libor was rapidly well established as the benchmark rate in the US dollar money market.[3] The Libor fixing is a measure of the rates paid on unsecured interbank deposits at large and internationally active banks. It is groundly speaking a benchmark giving an indication of the average rate a leading bank, for a given currency, can obtain unsecured funding for a given period in a given currency. It therefore represents the lowest real-world cost of unsecured funding in the London market.

Every day, the BBA surveys a panel of sixteen banks, asking them to provide the rates at which they could borrow "reasonable amounts" in a particular currency and maturity at 11:00 GMT. It refers to the interest rate at which banks in London offer to lend funds to each other just prior to that specific time. The fact that Libor is based on non-binding quotes, as opposed to actual transactions, may open up the possibility of strategic misrepresentation; the BBA tries to reduce the incentives for such behavior (and to remove quotes that are untypical for other reasons) by eliminating the highest and lowest quartiles of the distribution and averaging the remaining quotes. Quotes are ranked in order, the top and bottom quartiles are disregarded, and the middle two quartiles are averaged to compute the Libor rate.

Its uses are extremely important and of a large span. It serves as a reliable reference in a wide variety of financial contracts (bonds, loans, and derivative products) since the 1970s which is critical to the efficient functioning of markets in these instruments. The importance of benchmarks for short-term interest rates goes well beyond their practical use for contracts: they anchor the short end of the yield curve, thereby conveying information about expected future policy rates and other macroeconomic fundamentals. The terms of many financial derivatives also make explicit reference to Libor. Futures contracts on money market rates, and their over-the-counter equivalent, forward rate agreements, were developed in the early 1980s, along with interest rate swaps. Numerous other derivatives linked to money market rates followed, including swaptions, cross-currency swaps and asset swaps.

Libor is fixed for 15 different maturities, from overnight to twelve months, in ten international currencies (US dollar, euro and yen…).The sixteen contributing banks are selected based on their reputation, credit quality and activity in London. Foreign banks, large, internationally active dominate the Libor panels. Every contributor bank is asked to base their Libor submissions on the following question : *at what rate could you borrow funds, were you to do so, by asking for and then accepting inter-bank offers in a reasonable market size just prior to 11*

[3] It is computed at 11 hours London time, just before the opening of US markets. For further information the reader can refer to the BBA website.

am?[4] Therefore, submissions are based upon the lowest perceived rate that a bank on a certain currency panel could go into the inter-bank money market and obtain sizable funding, for a given maturity. Rates are not necessarily based on actual transactions, they are likely to reflect the true cost of interbank funding. A bank will know what its credit and liquidity risk profile is from rates at which it has dealt, can construct a curve to predict accurately the correct rate for currencies or maturities in which it has not been active. The liquidity crisis in the term segment of major interbank markets after the second semester 2007 has raised questions about the reliability of rate fixings like Libor. A comparison of alternative fixings for similar interest rates (Repo, OIS) seems to confirm that, during the turbulences, Libor diverged from other reference rates to an unusual extent. On Thursday, 29thMay 2008, the *Wall Street Journal* released a controversial study suggesting that banks may have understated borrowing costs they reported for Libor during the 2008 credit crunch. On 15thMarch 2011, an article in the FT mentioned that regulators in the US, Japan and UK are investigating whether some of the biggest banks conspired to manipulate the rate. On 7thSeptember 2011, some US investigation resumed into possible manipulation of interbank lending rates focused on violations of a commodities law. In the purpose of clarifying the debate, it is compulsory to have primarily an idea of the statistical dynamics of the Libor. So we turn now to the methodology and tests.

Methodology of Unit Root Tests with Break(s)

Three basic equations are estimated to test for the unit root versus structural breaks (Perron1989, Zivot and Andrews 1992- now ZA). Those specifications take into account the existence of three kinds of breaks: a crash model which allows for a break in the level or intercept of series (I);a changing growth model which allows for a break in the slope (II) and one that allows both effects to occur simultaneously (III):

$$x_t = \alpha_0 + \alpha_1 DU_t + d(DTB)_t + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \theta_i \Delta x_{t-i} + e_t \quad \text{(I)}$$

$$x_t = \alpha_0 + \gamma DT^*{}_t + \beta t + \rho x_{t-1} + \sum_{i=1}^{p} \theta_i \Delta x_{t-i} + e_t \quad \text{(II)}$$

$$x_t = \alpha_0 + \alpha_1 DU_t + d(DTB)_t + \gamma DT_t^* + \rho x_{t-1} + \sum_{i=1}^{p} \theta_i \Delta x_{t-i} + e_t \quad \text{(III)}$$

where k is the lag parameter, the intercept dummy DU_t represent a change in the level ; $DU_t = 1$ if t>date of the break (TB) and zero otherwise. The slope dummy DT_t^* represent a change in the slope of the trend function; $DT_t^* = t-TB$ if t>TB and zero otherwise. The crash dummy $DTB_t = 1$ if t= TB+1 and zero otherwise. In the abovementioned models, each specification has a unit root under the null hypothesis and the alternative hypothesis is a broken trend stationary process. The test is then performed using the ADF t-statistic for null hypothesis ρ=1 in the regression (I to III).ZA (1992) has the property of making the break date endogenous contrarily to Perron(1989). Perron(1997) assumes also an exogenous break, takes equations (I) and (III) as the two first cases but follows a two step procedure as a third case.[5] First, the series is detrended using the following regression:

$$x_t = \alpha_0 + \beta t + \gamma DT_t^* + \tilde{x}_t$$

The test is then performed using the t-statistic for α=1 in the regression:

[4] Question put in the official site of the BBA Libor.

[5] Procedures applying a filter before the test are called Additive Outliers (“AO”), those which detrend and test simultaneously are Innovational Outlier (“IO”).

$$\tilde{x}_t = \alpha\tilde{x}_{t-1} + \sum_{i=1}^{k}\theta_i\,\Delta\tilde{x}_{t-i} + e_t$$

For all tests, the endogenous break date is selected where the t-stat from the ADF test of unit root is at the minimum (most negative). In other words, a break date corresponds to the strongest rejection of the null hypothesis of non-stationarity. The main limit of the Perron or ZA approach is the impossibility to take into account more than one change in the trend. To circumvent this limit, Lumsdaine and Papell (1997) extended ZA (1992) method to accommodate two structural breaks, one in level and one in trend as well. In the same logics, Kapetanios (2005) allowed for up to five breaks. Setting up these tests[6] will allow us now to precise the pattern the Libor.

Data and Results

The series we used is the official daily Libor given by the British Bankers Association (BBA). The Libor maturities we studied are the most relevant ones for the market participants, namely 1 month and 3 months. The rates refer to three currencies, the US $, the British £ and the euro. The period is ranged between 3rd January 2005 and 30th September 2011. In figure 1, we plotted the rates, helping us graphically to point out some breaks in the dynamics, the strongest arising end September 2008 - our tests will allow us to give a more precise date for those breaks.

In Table 1, we reported the results of the classical unit root tests without break: ADF (1981), Phillips & Perron (1988) (null hypothesis: unit root) and Kwiatkowski, Phillips, Schmidt, Shin (1992) (null hypothesis: stationarity).All results[7] display a non-stationarity component in the series. This is in accordance with the intuitive feeling that there are significant breaks. Besides, Perron (1989) proved that the DF tests are biased in favor of the null hypothesis (unit root).

We present in Table 2 the results of unit root tests with one or two breaks(ZA, 1992, Perron, 1997 and Lumsdaine & Papell, 1997); in Table 3, we reported the results of unit root test with 'm' breaks (Kapetanios, 2005). Three methodological points are to be underlined regarding the tests. First, the lags are determined followed the "general to specific" procedure suggested by Perron (1989) and recommended by Ng & Perron (1995). At the beginning, we impose 12 lags(maximum) and we test the significance of the last term; if it is significant, the lag order is retained as 12, otherwise, we estimate 11 lags and so on ... This sequential procedure stops when the null hypothesis of insignificance is rejected at 10% level. Second, three alternative specifications (see equations above) are possible. There is no common criteria to select the best specification, consequently we chose to be exhaustive and reported all the results. Third, the location parameter i.e. the break date is obtained through the minimization of the ADF t-statistics or the minimization of the residual sum of squares for Kapetanios (2005).

The conclusions of those different tests are the following ones. Two of three available specifications of the ZA (1992) and Perron (1997) models lead to the same conclusion, namely

6 We will not use here the test of non linearity against stationarity like SETAR model (Hansen & Caner, 2001) because they impose to define an observable threshold variable. The break is then conditional to this variable whereas the determination of the time break is our objective in this present paper.

7 With all specifications (none, constant, constant and trend), we obtain the same result, namely the non-stationarity. We only report in table 1 the optimal specification. All others results are available upon request.

the rejection of the null hypothesis of a unit root. The break date for euro and dollar rates, in those models, appears to be always between the 8th and 10th October 2008.[8] One has to underline nevertheless a limit, namely we do not have any confidence interval at the break date, which can actually take place "around" the date specified by the model. That week began dramatically on the "Black Monday" 6th with the crash of the stock exchanges (Frankfurt: -7.16%, London: -5.48%, Madrid: -7.54%, New York-SP500: -7.61%, Paris: – 6.83%). Then, on the 8th October, seven central banks (USA, Europe, United Kingdom, China, Sweden, Switzerland and Canada) came to a historical agreement to decrease simultaneously their lending rates (marginal lending rate/discount rate, main refinancing rate/ fed fund rate and deposit rate) by 50 basis points. The rates proved to be very volatile: 3 months Euribor peaked at 5.39%, its highest level since the end of 1994, simultaneously one- week Euribor dropped at 4.79% after a maximum to 5.00% for the first time since seven years. For United Kingdom, the date is 3 weeks later. Note that this date takes place at the beginning of an accelerating falling phase of the rate, which actually starts near the 8th October (Fig.1). Another noticeable event happened on this date: seven British banks (Barclays, HBOS, Royal Bank of Scotland, Lloyds TSB, Standard Chartered, Nationwide et Abbey subsidiary of Santander) have been partially nationalized.

For the specification "3" for Perron and "2" for ZA, the null hypothesis is not rejected. This result is difficult to understand but we remark that the break date is very different according to those models and to the previous ones. This lack of robustness makes the results doubtful and we will go on the study by testing more breaks dates. In relation with this argument, Lumsdaine & Pappel (1997) proved that unit root tests that account for two significant breaks are more powerful than those that allow for a single break.

The results with Lumsdaine & Pappell test lead to homogenous conclusions: all tests reject the unit root hypothesis at 1%. In almost all cases, the first break date occurs at the same period as for the ZA and Perron tests. As for United Kingdom, we find a first break date that is the same as in the previous models – 4th of November. As for Euribor and US Libor three months, we have a date around 8th October. Concerning the second break date, it depends on the maturity of the rate and above all on the specification of the test. Conclusions are ambiguous since they are more explained by pure statistical properties than by obvious economic reasons.

Kapetanios' results are reported at Table 3. The model is available for 5 breaks maximum, We did let it run from 1 to 5 breaks, yet knowing that there is no indicator which selects the optimal number of breaks. A remark should be made at this step: the break selection is a sequential strategy; the second break is obtained for a fixed first break, there is no "refinement" (Bai 1997). The first comment is that the null hypothesis of unit root is rejected for specifications 1 and 3 for 1 to 5 breaks. The 8th October is always included in the break date and the others are relatively close in the different specifications. As for ZA model, specification 2 does not reject the null hypothesis. Besides, break dates are largely different within the set of those results and also compared to the other models. At last, the dates are not justified by any economic consideration.

Concluding Remarks

We have applied four tests of unit root with breaks. The conclusions are opposite to those without breaks, namely the reject of the null hypothesis of non-stationarity. This result is in

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[8] As usually mentioned in literature, Perron overestimates the break date by one period of time.

accordance with Perron's 1989 assertion. With the classical tests, it is anyway difficult to discriminate between non-stationarity and non linearity. Statistically, we have pointed out a date (8th October 2008) which is also economically coherent with macroeconomic events.

At least one extension is possible with this paper. We could go further in the enquiry on manipulation of the Libor rate to answer to some concerns raised by practitioners and academics regarding the fairness of the quote process of Libor. The present work is a prerequisite for that future study.

References

British Banker's Association, (2008), "BBA Libor Consultation", Feedback Statement, 5 August 2008,www.**bba**.org.**uk**/download/7515.

Bai, J. (1997), "Estimating multiple breaks one at a time", *Econometric Theory,* 13, 315-352.

Gyntelberg, J. andP.Wooldridge (2008), "Interbank rate fixing during the recent turmoil", *BIS Quaterly Review*, 59-72.

Kapetanios, G. (1999), "A test of m structural breaks under the unitroot hypothesis", NIESR Discussion Papers 152, National Institute of Economic and Social Research.

Kwiatkowski, D., P.C.B. Phillips., P. Schmidt and Y. Shin (1992), "Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?", *Journal of Econometrics,* vol. 54 (1-3), 159-178.

Lumsdaine, R.L. and D.H. Papell (1997), "Multiple Trend Breaks And The Unit-Root Hypothesis", *The Review of Economics and Statistics,* vol. 79(2), 212-218.

Mackenzie, D. and G.Tett (2008), "Speculation grows over Libor changes", *Financial Times*,10 June.

Mollenkamp, C. and M. Whitehouse (2008), "Study casts doubt on key rate", *Wall Street Journal*, 29 may.

Ng, S. and P. Perron (1997), "Estimation and inference in nearly unbalanced nearly cointegrated systems", *Journal of Econometrics,* vol. 79(1), 53-81.

Ng, S. and P. Perron (1995), "The Exact Error in Estimating the Special Density at the Origin", Cahiers de recherche 9535, Université de Montreal, Département de sciences économiques.

Perron P. (1989), "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", *Econometrica,* Econometric Society, vol. 57(6), 1361-1401.

Perron, P. (1997), "Further evidence on breaking trend functions in macroeconomic variables", *Journal of Econometrics,* vol. 80(2),355-385.

Rapach, D.E. and C.E. Weber, (2004), "Are real interest rates really nonstationary? New evidence from tests with good size and power", *Journal of Macroeconomics,* vol. 26(3), 409-430.

Zivot, E. and D.W.K. Andrews (1992). "Further Evidence on the Great Crash, the Oil-Price Shock, nd the Unit-Root Hypothesis", *Journal of Business & Economic Statistics,* vol. 10(3), 251-70.

Tables and Figures

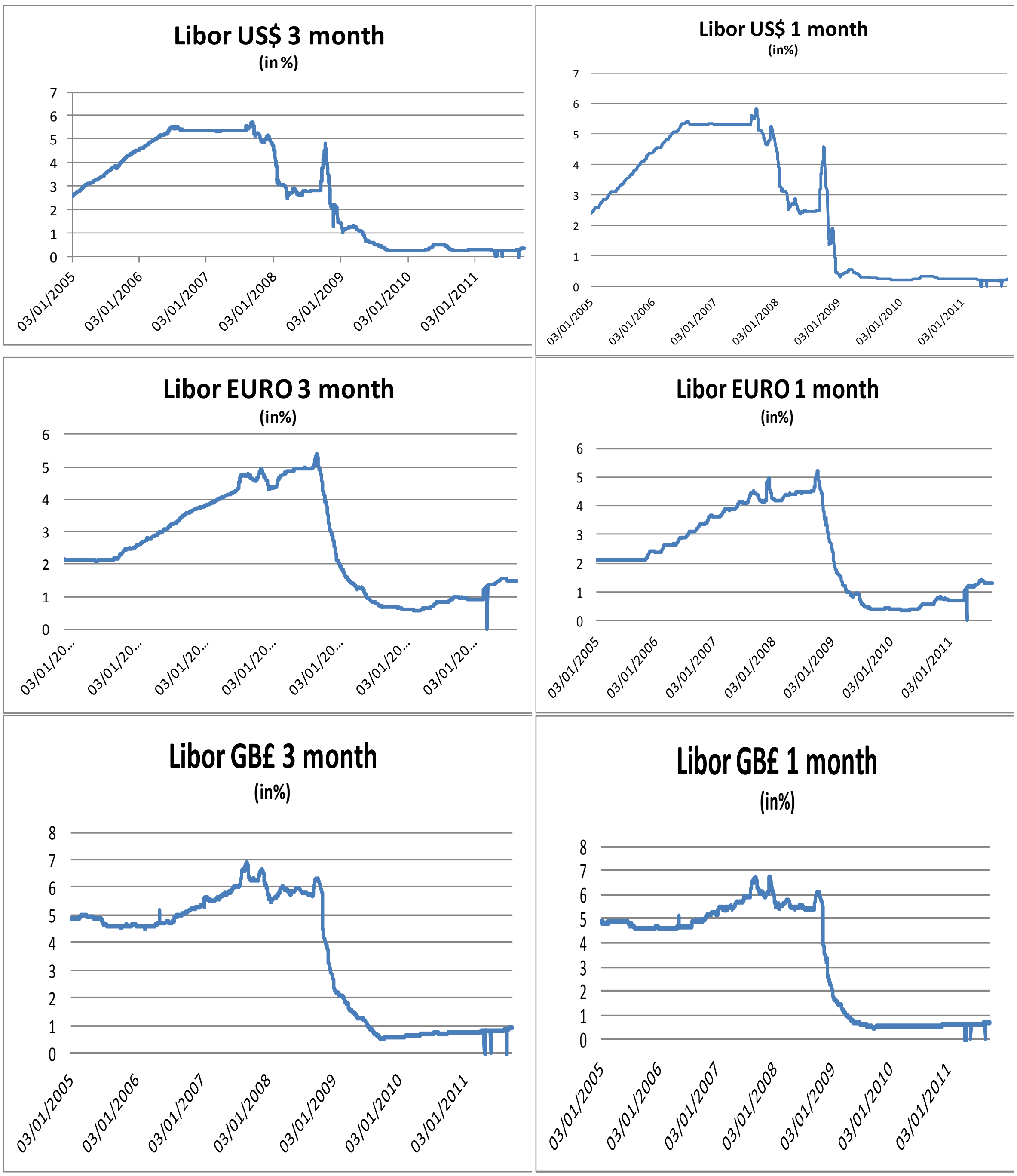

Figure 1. The Libor rate dynamics

Table 1. Classical unit root tests

	Libor EURO		Libor US$		Libor GBP	
	1Month	3 Months	1Month	3 Months	1Month	3 Months
ADF	-0.62a	-0.56a	-2.31c	-2.48c	-1.27a	-1.31a
	(0.44)	(0.47)	(0.42)	(0.33)	(0.18)	(0.17)
PP	-0.63 a	-1.22c	-2.38c	-2.49c	-1.28a	-1.34a
	(0.44)	(0.90)	(0.39)	(0.32)	(0.17)	(0.17)
KPSS	2.31*** b	0.91***c	0.70***c	0.74***c	3.86***b	3.74***b
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)

Notes : ADF is the Augmented Dickey-Fuller test, PP the Phillips-Perron test and KPSS the Kwiatkowski-Phillips-Schmidt-Shin test. (a) model without constant nor deterministic trend, (b) model with constant without deterministic trend, (c)) model with constant and deterministic trend. *, ** and *** denote rejection of the null hypothesis respectively at 10%, 5% and 1%. The number in parentheses is referred to the p-value of the test. For KPSS and PP tets, we need to determine the kernel and the bandwidth parameter; we choose the usual solution that is to use Bartlett kernel and Newey West (1994) data-based automatic bandwidth parameter method. The number of lagged difference terms of the dependent variable to be added to the ADF test is selected in the objective to remove serial correlation in the residual.

Table 2. Unit root tests with Break(s)

		LIBOR GBP 1 MONTH			LIBOR GBP 3 MONTHS		
Specification		a	b	C	a	b	C
	Statistics	-10.71	-1.81	-10.7	-9.61	-1.74	-9.25
	Conclusion	1%	H0	1%	1%	H0	1%
ZA (1992)	Break Date	04/11/08	25/09/06	04/11/08	04/11/08	14/09/06	04/11/08
	Statistics	-10.7	-10.7	-1.55	-9.61	-9.27	-1.42
	Conclusion	1%	1%	H0	1%	1%	H0
Perron (1997)	Break Date	03/11/08	03/11/08	06/04/11	03/11/08	03/11/08	25/05/11
	Statistics	-12.2	-12.1	-12.1	-12.6	-12.2	-12.2
	Conclusion	1%	1%	1%	1%	1%	1%
Lumsdaine et	Break Date 1	12/10/06	13/04/07	13/04/07	03/08/06	12/12/07	12/12/07
Papell (1997)	Break Date 2	04/11/08	04/11/08	04/11/08	04/11/08	04/11/08	04/11/08
		LIBOR EURO 1 MONTH			LIBOR EURO 3 MONTHS		
Specification		a	b	C	a	B	C
	Statistics	-9.21	-1.81	-7.91	-10.1	-1.81	-8.77
	Conclusion	1%	H0	1%	1%	H0	1%
ZA (1992)	Break Date	09/10/08	01/06/06	09/10/08	15/10/08	23/06/06	10/10/08
	Statistics	-9.18	-7.91	-1.41	-10.1	-8.76	-1.31
	Conclusion	1%	1%	H0	1%	1%	H0
Perron (1997)	Break Date	08/10/08	08/10/08	26/07/11	09/10/08	09/10/08	11/05/11
	Statistics	-9.58	-8.78	-8.78	-10.4	-9.73	-9.73
	Conclusion	1%	1%	1%	1%	1%	1%
Lumsdaine et	Break Date 1	27/08/08	17/12/07	17/12/07	25/10/05	10/10/08	10/10/08
Papell (1997)	Break Date 2	09/10/08	09/10/08	09/10/08	14/10/08	25/06/07	25/06/07
		LIBOR US$ 1 MONTH			LIBOR US$ 3 MONTHS		
Specification		a	b	C	A	B	C
	Statistics	-5.71	-2.67	-5.41	-5.75	-2.78	-5.24
	Conclusion	1%	H0	5%	1%	H0	10%
ZA (1992)	Break Date	10/10/08	06/10/05	10/10/08	10/10/08	29/09/05	10/10/08
	Statistics	-5.84	-5.48	-2.56	-5.90	-5.30	-2.61
	Conclusion	1%	1%	H0	1%	1%	H0
Perron (1997)	Break Date	09/10/08	09/10/08	03/09/10	09/10/08	09/10/08	16/12/10
	Statistics	-8.77	-7.91	-7.91	-7.92	-7.33	-7.33
	Conclusion	1%	1%	1%	1%	1%	1%
Lumsdaine et	Break Date 1	29/11/07	29/11/07	29/11/07	10/12/07	27/12/07	27/12/07
Papell (1997)	Break Date 2	10/10/08	27/11/08	27/11/08	10/10/08	13/10/08	13/10/08

Notes : Tstat is the statistic to test the null hypothesis of unit root. (a) crash model which allows for a break in the level or intercept of series; (b) a changing growth model which allows for a break in the slope and (c) one that allows both effects to occur simultaneously . 1%, 5% , 10%, H0 denote rejection of the null hypothesis respectively at 10%, 5% 1% and the non-rejection of H0 (p-value superior at 10%).

Table 3. Unit root tests with Kapetanios test

	LIBOR GBP 1 MONTH			LIBOR GBP 3 MONTHS		
Specification	a	b	c	a	b	C
Tstat 1 break	-10.7***	-1.80	-10.7***	-9.61***	-1.74	-9.25***
Tstat 2 breaks	-12.2***	-2.45	-12.1***	-10.6***	-2.36	-10.3***
Tstat 3 breaks	-12.6***	-3.32	-13.4***	11.0***	-3.11	-11.9***
Tstat 4 breaks	-13.7***	-3.71	-14.6***	-11.4***	-3.52	-13.3***
Tstat 5 breaks	-14.1***	-4.00	-15.8***	-11.7***	-3.71	-14.1***
Break 1	04/11/08	25/09/06	04/11/08	04/11/08	14/09/06	04/11/08
Break 2	12/10/06	07/12/09	13/04/07	03/08/06	29/01/10	12/12/07
Break3	13/04/07	07/08/07	17/12/07	05/01/07	01/08/07	03/02/06
Break 4	17/12/07	01/09/09	18/09/07	25/04/11	07/10/09	30/09/09
Break 5	12/09/08	27/05/08	15/09/08	16/04/07	14/05/08	08/08/07
	LIBOR EURO 1 MONTH			LIBOR EURO 3 MONTHS		
Specification	a	b	c	a	b	c
Tstat 1 break	-9.21***	-1.81	-7.91***	-10.1***	-1.81	-8.77***
Tstat 2 breaks	-9.86***	-2.31	-8.78***	-10.3***	-2.32	-9.73***
Tstat 3 breaks	-9.93***	-2.69	-9.52***	-10.4***	-2.58	-10.4***
Tstat 4 breaks	-10.0***	-2.91	-10.2***	-10.4***	-2.82	-10.8***
Tstat 5 breaks	-10.2***	-3.15	-10.6***	-10.6***	-3.16	-11.3***
Break 1	09/10/08	01/06/06	09/09/08	15/10/08	23/06/06	10/10/08
Break 2	27/08/08	14/05/10	17/12/07	25/10/05	25/05/10	25/04/11
Break3	07/11/05	21/05/07	24/04/11	02/09/08	29/05/07	17/12/07
Break 4	25/04/11	11/01/10	08/10/07	25/07/11	05/02/10	11/10/07
Break 5	15/11/10	29/11/07	20/08/08	04/04/11	08/08/07	08/08/07
	LIBOR US$ 1 MONTH			LIBOR US$ 3 MONTHS		
Specification	a	b	c	a	b	c
Tstat 1 break	-5.71***	-2.69	-5.41**	-5.75***	-2.78	-5.23**
Tstat 2 breaks	-8.77***	-3.29	-7.70***	-7.92***	-3.31	-7.18***
Tstat 3 breaks	-10.0***	-4.82	-10.1***	-9.08***	-4.86	-9.41***
Tstat 4 breaks	-10.7***	-5.61	-13.3***	10.5***	-5.47	-12.6***
Tstat 5 breaks	-11.1***	-6.14	-14.0***	-10.8***	-5.73	-13.0***
Break 1	10/10/08	06/10/05	10/10/08	10/10/08	29/09/05	10/10/08
Break 2	29/11/07	23/10/09	20/09/06	10/12/07	07/01/10	27/12/07
Break3	28/09/05	07/02/07	04/01/08	05/09/05	30/01/07	05/06/06
Break 4	28/08/08	14/05/09	28/08/08	28/08/08	28/08/09	28/08/08
Break 5	22/02/06	31/07/07	13/09/07	18/01/06	02/07/07	14/09/07

Notes (a) crash model which allows for a break in the level or intercept of series; (b) a changing growth model which allows for a break in the slope and (c) one that allows both effects to occur simultaneously .***, ** , * denote rejection of the null hypothesis respectively at 1%, 5%, 10%.Tstat "n" break corresponds to the stationarity test where "n" breaks are imposed. Break 1 to 5 corresponds to the break dates for a test at 5 breaks.

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