When Carry Trades in Currency Markets Are Not Profitable*

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Abstract

The success of the carry trade in international currency and money markets is related to the extent of the forward premium anomaly. We present evidence that the anomaly is a very time dependent phenomenon. We also formulate a model where the ex post returns from the carry trade are functionally related to the relative difference between the interest rate on the funding currency and the interest rate associated with the target currency; i.e. the Relative Interest Rate Opportunity (*RIRO*). We estimate a nonlinear smooth transition regime model which relates the *RIRO* to the returns on the carry trade, and the estimated transition function then represents the time periods when the carry trade was profitable and when it was not. The analysis indicates that the desirability of carry trading has declined and for many currencies has actually become unprofitable since the financial crisis of 2008.

JEL Classification: C22; F31; G01; G15

Keywords: Carry trades; Structural breaks; Speculation; Uncovered interest rate parity; Nonlinear smooth transition models

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*The authors are grateful to the editor, an anonymous referee, and seminar participants at Yonsei University, the Society for Nonlinear Dynamics and Econometrics 19th Annual Symposium, 2012 Korea International Economic Association Winter Conference for their helpful comments. All remaining errors are the authors' responsibility.

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1 Introduction

The existence of the carry trade is now a well documented phenomenon, where an investor borrows in a currency associated with a low interest rate country, which is known as a funding currency and then invests in a higher yielding, or target currency.[1] Carry trades are now considered to be one of the main motivations for currency trading. The intriguing aspect of the carry trade phenomenon is that agents are essentially engaged in short run positions and attempting to make quick profits before the high interest rate currency, that they have invested in, suffers a depreciation as expected from uncovered interest rate parity. Hence the agents are speculating on the violation of uncovered interest rate parity, or the existence of the forward premium anomaly.

Since Froot and Thaler (1990) it has become fashionable to assume the forward premium as an unchanging stylized fact in international finance. However, this is not always the case, and we show evidence in this paper of substantial time variation in both the existence and magnitude of the forward premium anomaly in many of the major currencies vis à vis the US dollar. The time varying slope coefficients show dramatic variation across time over the last thirty years. This has implications for the profitability or otherwise of the carry trade strategy. In particular, the financial crisis of 2008 has apparently led to a reversal of the anomaly for many currencies and the apparent collapse of a profit from carry trades for some currencies. We then formulate a hypothesis that the ex post returns from the carry trade are functionally related to the relative difference between the interest rate on the funding currency and the interest rate associated with the target currency. This latter variable is denoted as the Relative Interest Rate Opportunity (*RIRO*). Among others, Brunnermeier et al. (2008) show that carry trade profitability is related to the interest rate differential between the target currency and the funding currency (*RIRO*). They provide evidence that carry traders are exposed to high "crash risk", that is, when there is a large and positive interest rate differential between the target currency and the funding currency, carry trade returns are negatively skewed. We estimate a nonlinear smooth transition regime model which relates the *RIRO* to the returns on the carry trade. The model involves two regimes of profitability and non profitability for the carry trade; and there is a time dependent regime transition function. The empirical results of our analy-

[1] Under CIP the carry trade is equivalently implemented by selling forward currencies that are at a forward premium and buying currencies that are at a forward discount.

sis indicate that the desirability of carry trading had declined for many currencies and has not been an attractive strategy in recent times. We also relate the estimated regime transition function to breaks in the forward premium and show that generally sharp changes in monetary policy have not had a predictable effect on the transition function and the profitability of the carry trade.

The plan of the paper is as follows; the next section provides empirical evidence on the time variability of the forward premium anomaly. Section 3 presents a model where the returns on the carry trade depends on the *RIRO*, which intuitively measures the extent of the opportunity of the carry trade. We estimate a model that relates the returns on the carry trade to a transition function that is dependent on the *RIRO* and shows the switches from regimes of profits to regimes of losses and vice versa. Several countries have recently switched into regimes where the carry trade is likely to make substantial losses. The next section finds evidence of structural breaks in many countries forward premium series. Subsequent analysis shows that these breaks are generally not useful in predicting changes in the transition function for returns to carry trades switching regimes. The final section provides a brief conclusion.

2 Time Varying Forward Premium Anomaly

On defining s_t as the logarithm of the spot exchange rate quoted as the foreign price of domestic currency, and i_t and i_t^* are the one period risk free domestic and foreign interest rates, respectively. The ex post returns y_{t+1} from a carry trade are then

$$y_{t+1} = \Delta s_{t+1} - (i_t^* - i_t) \tag{1}$$

and the success of the carry trade, clearly requires a positive ex post return, so that the interest rate differential has predictive content on future currency returns. Under uncovered interest rate parity, the expected rate of return on a currency should equal the interest rate differential, so that

$$E_t \Delta s_{t+1} = i_t^* - i_t = f_t - s_t, \tag{2}$$

where E_t is the conditional expectations operator on a sigma field of all relevant information up to and including time t and where f_t is the logarithm of the forward rate for a one period ahead transaction. A standard test of *UIP* has been to estimate the regression:

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + u_{t+1}. \tag{3}$$

Under *UIP*, the null hypothesis is that $\alpha = 0$, $\beta = 1$, and that the error term, u_{t+1}, is serially uncorrelated. The standard perceived wisdom is, following Fama (1984), that there exists the so called forward premium anomaly, where the estimate of the slope coefficient is negative and significantly different from unity. In a widely cited study Froot and Thaler (1990) find over 75 published studies that the average estimated value of β is -0.88. Explanations of the anomaly range from the presence of time-dependent risk premia, e.g., Hodrick (1989) and Mark and Wu (1997); to possible peso problems, segmented markets and heterogenous trading behavior. Also, Maynard and Phillips (2001) and Baillie and Bollerslev (2000) have considered some econometric issues arising from the relatively uncorrelated spot returns being regressed on the lagged forward premium, which has very persistent autocorrelation. However, virtually all of this literature assumes the existence of the anomaly and then seeks to explain it. However, some work has noted the asymmetry of the anomaly and Wu and Zhang (1996), Bansal (1997) and Zhou (2002) have all noted that the forward premium anomaly tends to be more extreme with larger negative slope coefficient estimates, when *US* interest rates were below foreign equivalents. So, the sign of the forward premium, $(f_t - s_t)$, is an important indicator on the magnitude of the anomaly. Baillie and Kiliç (2006) have found similar asymmetries arise with relative money growth rates, variability of monetary growth all influencing the duration and magnitude of the anomaly. Some other important evidence concerning the anomaly is provided by Lothian and Wu (2011) who examine two hundred years of data and find that the negative beta coefficient is very much affected by data in the 1980s. Overall, large interest rate differentials tend to have significantly stronger forecasting powers for currency movements than smaller interest rate differentials. However, the popularity of the carry trade is reputedly a relative recent phenomenon. One way of analyzing this is to consider the model with time varying beta, given by

$$\Delta s_{t+1} = \alpha + \beta_t(f_t - s_t) + u_{t+1} \tag{4}$$

where the very nature of β_t being time dependent signifies the forward premium anomaly can move from being *severe* to *minimal* across a realization. Figure 1 below graphs the estimates of β_t derived from a five year rolling regression for eight different currencies against the *US* dollar for data from December 1988 through October 2010; which gives a sample size of 263 observations. The eight freely floating currencies are deliberately chosen to be separate from the Eurozone and have therefore existed for the complete twenty two year period. They are the Australian dollar (*AUD*), the Canadian dollar (*CAD*), Swiss franc (*CHF*), Danish krone (*DKK*), Japanese yen (*JPY*), UK pound (*GBP*), Norwegian krone (*NOK*) and the New Zealand dollar (*NZD*). It can be seen that there are many periods where the β_t is significantly negative and other periods particularly towards the end of the sample, where its value becomes relatively high and sometimes exceeds unity. For example, the New Zealand dollar (*NZD*) has a β_t that is consistently negative from 2001 through 2008 and is as small as -10 in some periods. However, after 2008 it is large and positive and $+10$ with two sided 95% confidence intervals easily exceeding unity. In general the financial crisis of the Fall of 2008 with lower nominal interest rates has coincided with the *AUD*, *CHF*, *NOK* and *NZD* all having large and positive β_t coefficients from the rolling regression and imply a reversal of the anomaly. Hence a country with the higher interest rate has a *greater* depreciation than implied by *UIP*.

Another interesting aspect is that the shapes of the estimated β_t graphed over time are quite similar between currencies. Hence the presence of the anomaly and reversal of the anomaly appear to be inter-related over time and also across currencies. The method for estimating the β_t can alternatively be derived from more formal Kalman Filtering methods or from a model involving regime switching where *UIP* holds for part of the sample, and where the anomaly is only present for some periods. However, the simple rolling regressions reported here seem clear enough to capture the basic characteristics of the phenomenon.

3 Model for Carry Trading

Our interest is primarily directed at when the carry trade can be profitable. As defined previously, the ex post returns y_{t+1} from a carry trade are

$$y_{t+1} = \Delta s_{t+1} - (i_t^* - i_t) \tag{5}$$

and then these returns can also be decomposed into $y_{t+1} = q_{t+1} + r_{t+1}$ where q_{t+1} is the deviations from relative purchasing power parity, $q_{t+1} = \Delta s_{t+1} + [\Delta p_t^* - \Delta p_t]$ and $r_{t+1} =$

$[i_t^* - i_t] - [\Delta p_t^* - \Delta p_t]$, which is the real interest rate differential. However, the most informative way of assessing the profitability, or otherwise, of the carry trade is a nonlinear function of the *RIRO*, which is denoted by z_t and is derived from the fact that there are three principal alternative funding currencies that have had the lowest interest rates among all developed country currencies over the sample period; namely the *US* dollar (*USD*), the Japanese yen (*JPY*), and the Swiss franc (*CHF*). In particular, *RIRO* occurs when the *USD* is defined to be the preferred funding currency if

$$z_t = \min\{i_t^{JPY}, i_t^{CHF}\} - i_t^{USD} > 0, \tag{6a}$$

so that all else being equal the attractiveness of the dollar as a funding currency, the most important comparison is between the *USD* and the next lowest cost currency. Similarly, the yen is the preferred funding currency if:

$$z_t = \min\{i_t^{USD}, i_t^{CHF}\} - i_t^{JPY} > 0, \tag{6b}$$

and the Swiss franc is the preferred funding currency if:

$$z_t = \min\{i_t^{USD}, i_t^{JPY}\} - i_t^{CHF} > 0. \tag{6c}$$

Given the limits to speculation hypothesis of Lyons (2001),[2] when either (6a), (6b), or (6c) holds and the size of the differentials is large, then there should be an increased probability that *UIP* will be valid for exchange rates expressed with either the *USD*, *JPY*, or *CHF* as the numeraire currency, respectively. Conversely, the breakdown of (6a), (6b), or (6c) should lead to an increased probability of the forward premium anomaly.

The returns from the carry trade is related to the *RIRO* by

$$y_{t+1} = [\alpha_1 + \beta_1(i_t^* - i_t)]\,(1 - G(z_t;\gamma,c)) + [\alpha_2 + \beta_2(i_t^* - i_t)]\,G(z_t;\gamma,c) + u_{t+1} \tag{7}$$

where $G(\cdot)$ is a transition function and, u_{t+1} is a zero mean, stationary $I(0)$ disturbance term. If the Δs_{t+1} is the Yen-\$ and $\min\{i_t^{USD}, i_t^{CHF}\} = i_t^{USD} = i_t$, then $z_t = (i_t - i_t^*)$. The above logistic function is bounded between 0 and 1, and depends on the transition variable z_t. Namely,

[2] The existence of higher than usual profit opportunities from conducting carry trades attracts speculative capital and induces agents to trade these profit opportunities away. Conversely, when carry profits appear low or negative, the forward bias is left unexploited and thereby persists.

$G(z_t; \gamma, c) \to 0$ as $z_t \to -\infty$, $G(z_t; \gamma, c) = 0.5$ for $z_t = c$, and $G(z_t; \gamma; c) \to 1$ as $z_t \to +\infty$. When $\gamma \to \infty$, $G(z_t; \gamma, c)$ becomes a step function, so that the smooth transition model becomes effectively a discrete switching model. For $\gamma = 0$, $G(z_t; \gamma, c) = 0.5$ for all z_t, in which case the model reduces to a linear regression model with the slope parameter $\beta = 0.5\beta_1 + 0.5\beta_2$. The above *LSTR* model is related to the *LSTAR* and other non-linear time series models introduced by Granger and Teräsvirta (1993), Teräsvirta (1994), and van Dijk et al. (2002). The *LSTR* modeling approach is well suited for our purposes because it allows for smooth and continuous adjustment between regimes, the rate of which in turn depends on the state of specified transition variables.

If the carry trade is not profitable then $G(\cdot)$ approaches unity. From (7), this corresponds to an upper regime consistent with *UIP* given by:

$$y_{t+1} = \alpha_2 + \beta_2(i_t^* - i_t) + u_{t+1}, \tag{8}$$

with $\alpha_2 = 0$ and $\beta_2 = 0$. In this case, there should be no ex post returns from the carry trade on average since *UIP* holds. Conversely, when the carry trade is profitable then $G(\cdot)$ approaches zero, and the model will be in the lower regime, corresponding to:

$$y_{t+1} = \alpha_1 + \beta_1(i_t^* - i_t) + u_{t+1}, \tag{9}$$

where β_1 is consistent with the forward premium anomaly. The *RIRO*, which involves the non linear function of interest rates is hypothesized to have some impact on the returns. In the set up of this model the upper regime is where the carry trade is not profitable and the lower regime is where it is profitable. The transition function hence moves between periods of profitability and loss according to the logistic function,

$$G(z_t; \gamma, c) = (1 + \exp(-\gamma(z_t - c)/\sigma_{z_t}))^{-1}, \quad \gamma > 0 \tag{10}$$

where z_t is the transition variable, σ_{z_t} is the standard deviation of z_t, γ is a slope parameter, and c is a location parameter. The exponent in (10) is normalized by dividing by σ_{z_t}, which allows the parameter γ to be approximately scale free.

Hence the behavior of the β_t and hence the extent or duration of the forward premium anomaly are components of the potential profitability of the carry trade. The main issue concerns the choice of transition variables that would lead to an investor taking a position on the carry trade. Profit maximizing investors would clearly prefer to fund carry trades with the lowest cost currency. Moreover, the lower the interest rate on this *preferred funding currency* relative to alternative funding currencies, then the more attractive it is to fund carry trades with this particular currency. As more speculative capital is directed towards conducting carry trades with the preferred funding currency, Lyons' (2001) limits to speculation hypothesis predicts that excess returns from the strategy will be eliminated and reversion to *UIP* will occur.

The estimated models are reported in Table 1 and Figure 2 shows the graph of the transition functions over time. The estimated transitions for *AUD*, *CHF*, *NOK* and *NZD* are all close to unity the last two years of the sample, indicating the lack of profitability of the carry trade in this period of time.

The periods of profitability of the carry trade can be aggregated and summarized into Table 2 which gives the average return, and Sharpe ratio for the carry trades over this time. Consistent with the findings of Brunnermeier et al. (2008), carry trades that are exposed to a high "crash risk"; i.e. when there is a large, positive carry, or large and positive interest differential between the target currency and the funding currency, leads to severe conditional negative skewness.

4 Discontinuities in Forward Premium and Transition Function

One of the important aspects of the currency markets concerns the possibility of sudden changes in expectations leading to revisions as to the profitability of the carry trade. A certain amount of information on this can be obtained from the interest rate differential, $(i_t^* - i_t)$, which signifies relative changes in monetary policy. Equivalently the same information can be obtained from the forward premium, $(f_t - s_t)$. Some previous studies such as Baillie and Bollerslev (1994) and Maynard and Phillips (2001) have found evidence of long memory, or fractional integration, of the forward premium. More recently, Choi and Zivot (2007) find evidence for long memory in separate sub regimes of the forward premium. In the following, we use the multiple mean break methodology of Bai and Perron (1998, 2003) to detect possible structural changes in the forward premium. The m break model and the $m + 1$ regime model are defined as

$$(f_t - s_t) = c_j + u_t, \quad t = T_{j-1} + 1, T_{j-1} + 2, ..., T_j \tag{11}$$

where $j = 1, 2, ..., m + 1$, and $T_0 = 0$, $T_{m+1} = T$, and c_j is the mean of the forward premium for each regime. For each one of the m partitions, the *OLS* estimate of the parameter c_j is obtained by minimizing the quantity,

$$S_T = \sum_{j=1}^{m+1} \sum_{t=T_j-1}^{T_j} (y_t - c_j)^2. \tag{12}$$

Most of the forward premium series are found to have four or five break points and the graphs of the series together with their break points are plotted alongside the estimated transition functions in Figure 2. The estimated regime transition functions, $\hat{G}(z_t; \hat{\gamma}, \hat{c})$ were then regressed on the dummy variables corresponding to the $m = 5$ break points for each forward premium series.

$$\hat{G}(z_t; \hat{\gamma}, \hat{c}) = \alpha + \sum_{j=1}^{m} \omega_j D_{j,t} + v_t, \tag{13}$$

where $D_{j,t}$ are dummy variables corresponding to the break points in the forward premium. A summary of the results is available from the authors on request, but is omitted in the interests of conserving space. The parameters associated with the break points are statistically significantly different from zero and have a direct effect on the estimated regime transition function. However, they only account for relatively small amount of the variation, and past and current movements in the *RIRO* are very important for the behavior of the estimated transition function and the implied profitability of the carry trade. Hence breaks points in the forward premium only convey part of the information that influences the profitability or otherwise of the carry trade.

5 Conclusion

This paper has considered the widely discussed carry trade where an investor borrows in a currency associated with a low interest rate country, which is known as a funding currency and then invests in a higher yielding, or target currency. The successful implementation of carry trades depends on the violation of uncovered interest rate parity, and hence the existence of the forward premium anomaly. We show that there is substantial time variation in both the existence and magnitude of the forward premium anomaly in many of the major currencies vis à vis the *US* dollar. We formulate a model where ex post returns from the carry trade are functionally related to the relative difference between the interest rate on the funding currency and the interest rate associated with the target currency. We estimate a nonlinear smooth transition regime model which relates the target interest rate to the returns on the carry trade. The estimated transition clearly indicates periods when the carry trade was profitable and periods when it was not. The analysis indicates that the desirability of carry trading had declined for many currencies and may not be an attractive strategy in the near future following the 2008 financial crisis.

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TABLE 1. MODEL OF EX POST RETURNS OF CARRY TRADES WITH THE *RIRO* AS THE TRANSITION VARIABLE

$$y_{t+1} = \left[\alpha_1 + \beta_1\left(i_t^* - i_t\right)\right]\left(1 - G\left(z_t;\gamma,c\right)\right) + \left[\alpha_2 + \beta_2\left(i_t^* - i_t\right)\right]G\left(z_t;\gamma,c\right) + u_{t+1},$$
$$\text{where } G(\cdot) = \left[1 + \exp\left(-\gamma\left(z_t - c\right)/\sigma_{z_t}\right)\right]^{-1}, \text{ with } z_t = \min\left\{i_t^{CHF}, i_t^{JPY}\right\} - i_t^{USD}$$

	AUD	*CAD*	*CHF*	*DKK*	*GBP*	*JPY*	*NOK*	*NZD*
Lower regime: $G(\cdot) = 0$								
α_1	0.015	-0.001	-0.009	-0.003	0.002	-0.007	0.006	0.011
	(0.009)	(0.002)	(0.003)	(0.002)	(0.003)	(0.008)	(0.006)	(0.017)
β_1	2.779	-2.053	-4.433	-4.595	-2.793	-3.488	-1.903	-2.868
	(3.678)	(0.843)	(1.120)	(1.388)	(1.496)	(1.858)	(2.569)	(4.322)
Upper regime: $G(\cdot) = 1$								
α_2	-0.003	-0.003	0.034	-0.000	-0.017	-0.006	-0.006	-0.022
	(0.004)	(0.012)	(0.016)	(0.008)	(0.026)	(0.005)	(0.004)	(0.009)
β_2	-1.231	1.282	-13.151	-0.537	4.802	0.766	0.499	4.725
	(1.039)	(5.213)	(5.789)	(1.139)	(6.397)	(5.106)	(0.927)	(2.610)
Transition parameters:								
γ	15.260	6.374	35.287	17.174	16.018	2.833	8.449	3.879
	(1.436)	(3.949)	(0.869)	(2.940)	(3.091)	(3.190)	(1.548)	(1.659)
c	-0.004	·	·	-0.001	·	·	-0.003	-0.003
	(0.000)			(0.000)			(0.000)	(0.001)
Wald	8.644	0.069	5.229	0.505	0.626	2.009	3.651	10.119
$t_{\beta_2=0}$	-1.184	0.246	-2.272	-0.471	0.751	0.150	0.538	1.810
T	263	263	263	263	263	263	263	263

Note. Newey-West (robust) standard errors are in parentheses below the corresponding parameter estimates. *Wald* denotes the robust *Wald* statistic for testing H_0: $\alpha_2 = 0$ and $\beta_2 = 0$ which is asymptotically χ^2 distributed with two degrees of freedom. $t_{\beta_2=0}$ is the robust t-statistic for testing the null hypothesis of H_0: $\beta_2 = 0$. T denotes the sample size. For the *JPY* and *NOK*, the transition variable is the (*CHF*$-$*USD*) interest rate differential.

TABLE 2. PERFORMANCE OF CARRY TRADES IN REGIMES WHEN *UIP* IS INVALID

	CAD	*CHF*	*DKK*	*JPY*
Average return	0.0015	0.0005	0.0005	0.0058
Std. Dev.	0.0147	0.0304	0.0280	0.0394
Sharpe ratio	0.1032	0.0149	0.0172	0.1473
Skewness	-0.0028	-0.5472	-0.1654	-1.6816

Note. Statistics for the carry trade in the subperiod when *UIP* does not tend to hold are reported. Only currencies that have a considerable period for the lower regime have been included.

TABLE 3. MULTIPLE STRUCTURAL CHANGE TESTS

Statistic	Currency (vis-à-vis the *US* Dollar)							
	AUD	*CAD*	*CHF*	*DKK*	*GBP*	*JPY*	*NOK*	*NZD*
Tests								
$\sup F_T(1)$	52.992***	65.219***	22.859***	16.485***	56.069***	3.843	8.625*	8.419*
$\sup F_T(2)$	32.484***	40.579***	45.589***	16.406***	51.004***	14.382***	7.249	33.271***
$\sup F_T(3)$	39.829***	51.483***	13.833***	21.325***	32.082***	8.901**	9.887***	19.623***
$\sup F_T(4)$	48.950***	40.376***	14.374***	18.804***	40.035***	150.782***	15.107***	10.017***
$\sup F_T(5)$	38.387***	43.220***	56.830***	17.605***	62.802***	100.124***	8.324***	16.071***
$\text{UD}_{\max}$	52.992***	65.219***	56.830***	21.325***	62.802***	150.782***	15.107***	33.271***
$\text{WD}_{\max}$	78.204***	74.768***	98.312***	30.906***	108.643***	240.896***	24.136***	41.262***
$\sup F_T(2\|1)$	10.884**	6.260	36.668***	11.255**	2.560	17.765***	5.738	6.062
$\sup F_T(3\|2)$	20.392***	5.059	8.873	7.771	1.472	3.309	3.636	18.653***
$\sup F_T(4\|3)$	10.312	6.186	16.742***	7.771	14.249**	6.792	22.018***	7.416
$\sup F_T(5\|4)$	3.861	38.527***	9.168	15.446**	4.032	13.510**	11.137*	5.703
Number of breaks selected								
Sequential	1	1	3	2	1	0	0	0
LWZ	5	5	5	5	5	5	5	5
BIC	5	5	5	5	5	5	5	5

Note. The test results for multiple structural changes in the forward premium as in Bai and Perron (1998, 2003) are reported. *, **, *** indicate 10%, 5%, 1% statistical significance, respectively.

TABLE 4. ESTIMATES FOR MULTIPLE STRUCTURAL BREAK MODELS

AUD				*CAD*			
$\hat{c}_1$	0.603 (0.017)	$\hat{T}_1$	91:03 [90:12, 91:08]	$\hat{c}_1$	0.276 (0.010)	$\hat{T}_1$	93:02 [92.02, 93:08]
$\hat{c}_2$	0.165 (0.011)	$\hat{T}_2$	96:11 [95:08, 98:01]	$\hat{c}_2$	0.071 (0.012)	$\hat{T}_2$	96:03 [95:10, 97:01]
$\hat{c}_3$	-0.019 (0.012)	$\hat{T}_3$	01:08 [01:05, 02:02]	$\hat{c}_3$	-0.161 (0.015)	$\hat{T}_3$	97:12 [97:07, 99:11]
$\hat{c}_4$	0.278 (0.014)	$\hat{T}_4$	05:05 [05:01, 06:01]	$\hat{c}_4$	-0.046 (0.011)	$\hat{T}_4$	01:03 [97:09, 01:04]*
$\hat{c}_5$	0.098 (0.016)	$\hat{T}_5$	07:12 [07:07, 08:03]	$\hat{c}_5$	0.087 (0.011)	$\hat{T}_5$	04:11 [04:05, 09:07]*
$\hat{c}_6$	0.308 (0.016)			$\hat{c}_6$	-0.029 (0.008)		

CHF				*DKK*			
$\hat{c}_1$	-0.166 (0.027)	$\hat{T}_1$	89:12 [88:12, 90:01]	$\hat{c}_1$	0.064 (0.031)	$\hat{T}_1$	91:03 [90:10, 92:01]
$\hat{c}_2$	0.166 (0.013)	$\hat{T}_2$	94:08 [94:08, 08:10]*	$\hat{c}_2$	0.429 (0.043)	$\hat{T}_2$	92:06 [90:07, 92:09]
$\hat{c}_3$	-0.310 (0.011)	$\hat{T}_3$	00:12 [00:03, 01:02]	$\hat{c}_3$	0.863 (0.043)	$\hat{T}_3$	93:09 [93:01, 94:07]
$\hat{c}_4$	-0.076 (0.014)	$\hat{T}_4$	05:01 [04:10, 06,01]	$\hat{c}_4$	0.207 (0.046)	$\hat{T}_4$	94:10 [94:03, 97:07]
$\hat{c}_5$	-0.270 (0.017)	$\hat{T}_5$	07:12 [07:11, 08:03]	$\hat{c}_5$	-0.123 (0.019)	$\hat{T}_5$	00:12 [97:08, 04:08]
$\hat{c}_6$	-0.050 (0.017)			$\hat{c}_6$	0.021 (0.015)		

GBP				*JPY*			
$\hat{c}_1$	0.390 (0.019)	$\hat{T}_1$	89:12 [89:08, 95:09]*	$\hat{c}_1$	-0.315 (0.023)	$\hat{T}_1$	89:12 [88:12, 91:02]
$\hat{c}_2$	0.519 (0.012)	$\hat{T}_2$	92:10 [92:09, 93:01]	$\hat{c}_2$	0.010 (0.011)	$\hat{T}_2$	94:08 [94:08, 00:10]*
$\hat{c}_3$	0.244 (0.018)	$\hat{T}_3$	94:01 [91:06, 94:02]	$\hat{c}_3$	-0.435 (0.009)	$\hat{T}_3$	01:08 [01:06, 01:11]
$\hat{c}_4$	0.054 (0.007)	$\hat{T}_4$	01:08 [00:12, 05:07]	$\hat{c}_4$	-0.138 (0.013)	$\hat{T}_4$	05:01 [02:10, 05:03]
$\hat{c}_5$	0.207 (0.010)	$\hat{T}_5$	05:05 [04:11, 06:03]	$\hat{c}_5$	-0.347 (0.012)	$\hat{T}_5$	08:09 [08:08, 09:10]
$\hat{c}_6$	0.039 (0.009)			$\hat{c}_6$	-0.038 (0.017)		

NOK				*NZD*			
$\hat{c}_1$	0.224 (0.035)	$\hat{T}_1$	91:05 [88:12, 91:07]*	$\hat{c}_1$	0.385 (0.013)	$\hat{T}_1$	91:07 [90:10, 92:11]
$\hat{c}_2$	0.723 (0.039)	$\hat{T}_2$	93:05 [93:03, 95:01]	$\hat{c}_2$	0.219 (0.008)	$\hat{T}_2$	98:07 [97:07, 98:11]
$\hat{c}_3$	-0.008 (0.020)	$\hat{T}_3$	01:02 [97:09, 01:10]	$\hat{c}_3$	-0.027 (0.012)	$\hat{T}_3$	01:04 [00:09, 01:11]
$\hat{c}_4$	0.340 (0.033)	$\hat{T}_4$	03:11 [03:03, 06:03]	$\hat{c}_4$	0.292 (0.008)	$\hat{T}_4$	07:11 [06:12, 09:05]*
$\hat{c}_5$	-0.079 (0.028)	$\hat{T}_5$	07:11 [07:02, 10:02]	$\hat{c}_5$	0.458 (0.020)	$\hat{T}_5$	08:12 [08:11, 09:08]
$\hat{c}_6$	0.173 (0.032)			$\hat{c}_6$	0.215 (0.015)		

Note. $\hat{c}_i$ is the estimated intercept parameter and $\hat{T}_i$ is the estimated break date. Asymptotic standard errors are in parenthesis next to the corresponding parameter estimates. The 95% confidence intervals are reported in brackets. * indicates the 90% confidence interval.

FIGURE 1. SLOPE ESTIMATES FROM ROLLING *UIP* REGRESSIONS USING 5-YEAR SUBSAMPLES. THE DASHED LINE REPRESENTS 95 PERCENT CONFIDENCE BANDS.

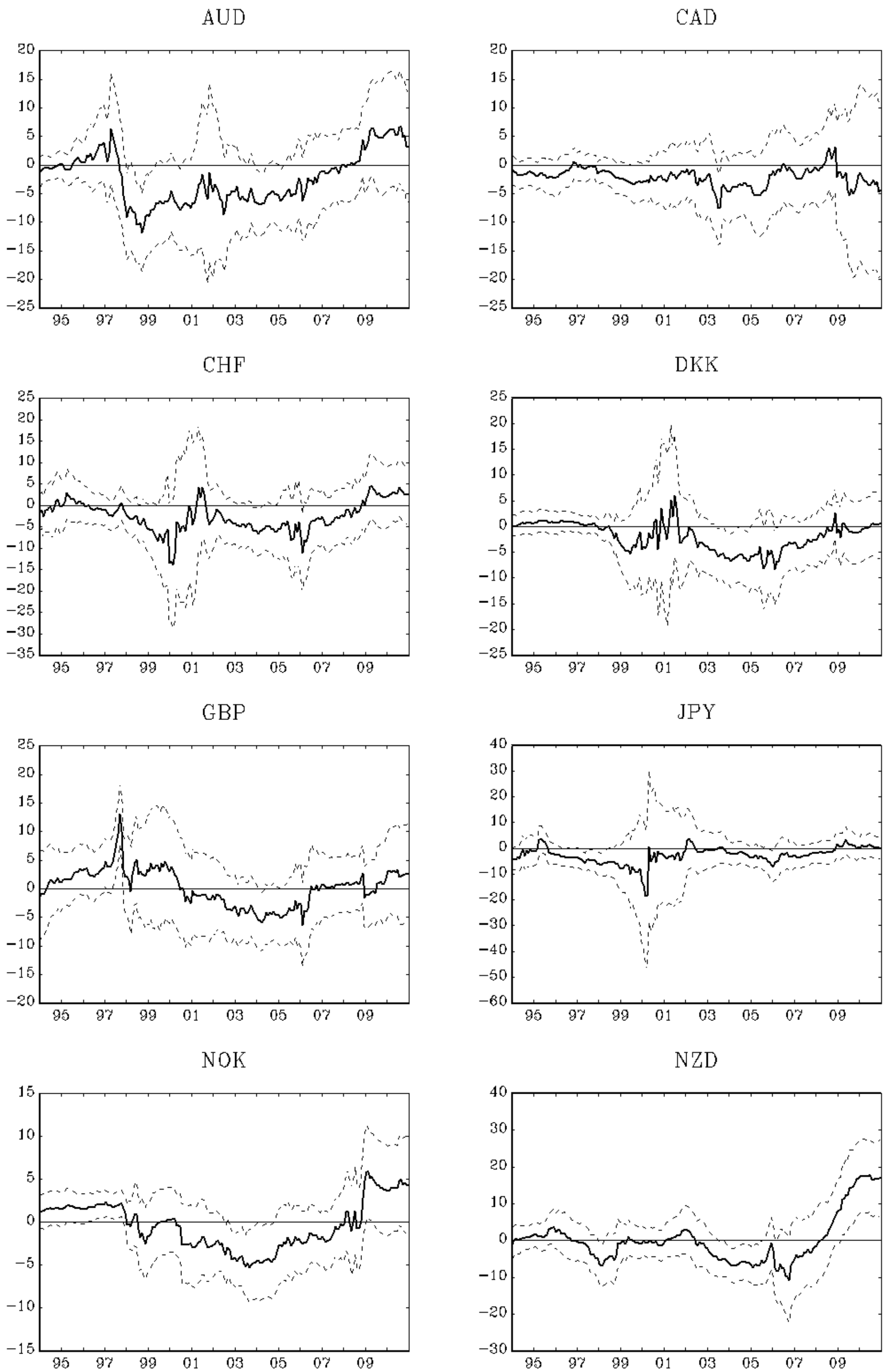
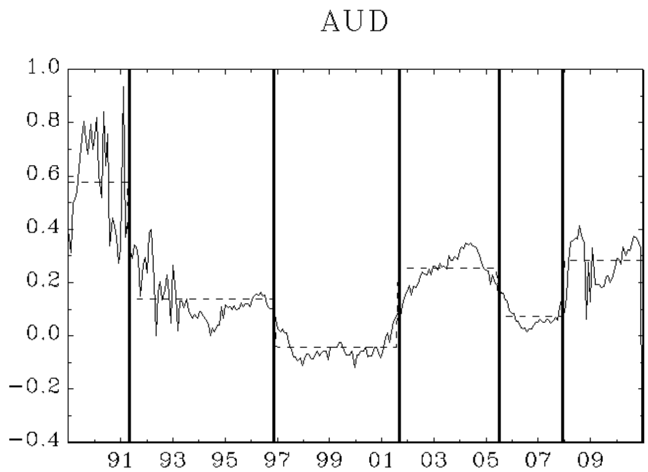


FIGURE 2. TOP: ESTIMATED BREAK DATES FOR THE FORWARD PREMIUM (VIS-À-VIS THE *US* DOLLAR). THE DIFFERENCES IN RATES ARE REPORTED IN PERCENTAGES, BOTTOM: THE ESTIMATED TRANSITION FUNCTION OVER TIME FROM THE *LSTR* MODEL.



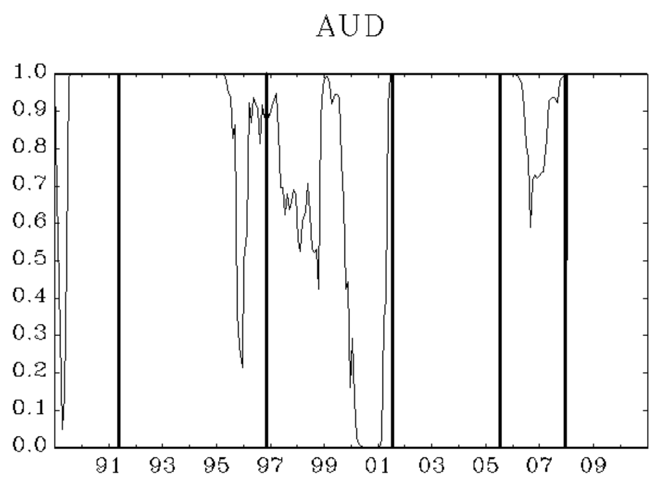
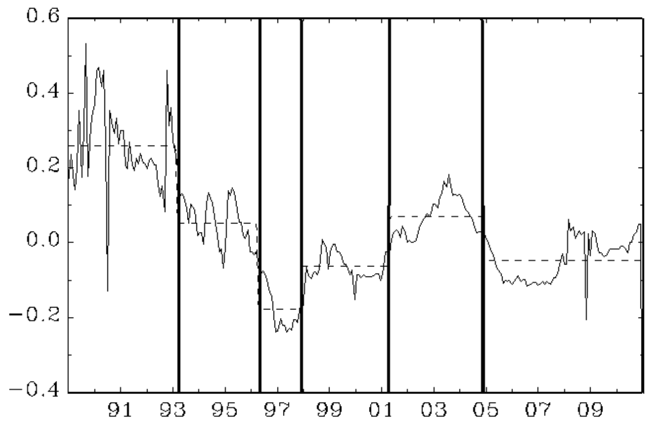


FIGURE 2. (CONT'D)

CAD



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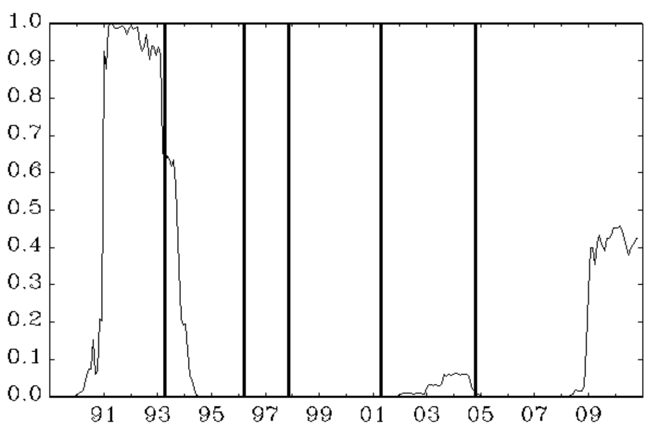
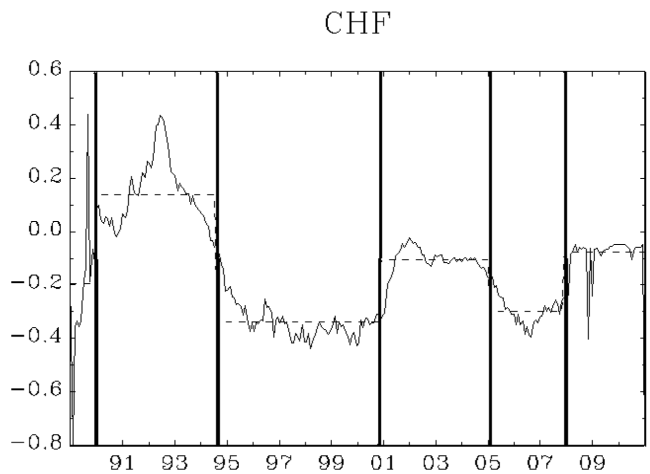


FIGURE 2. (CONT'D)



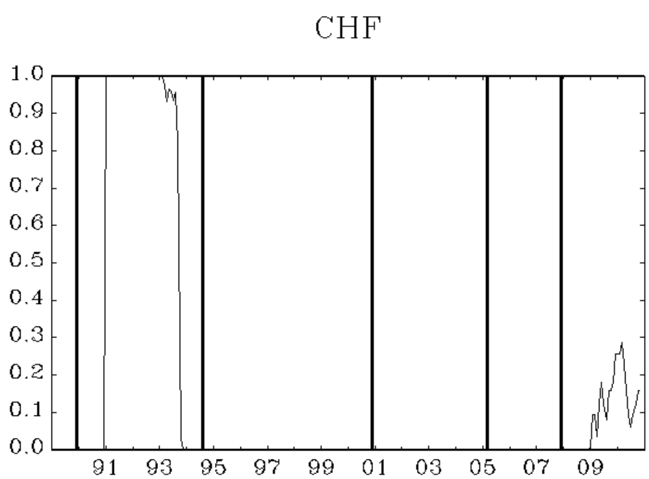
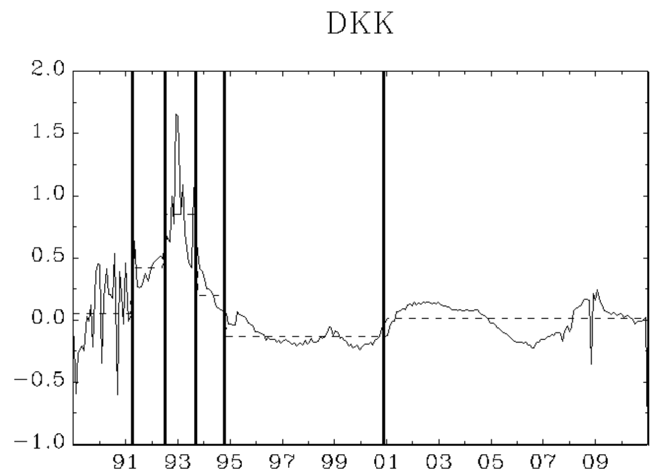


FIGURE 2. (CONT'D)



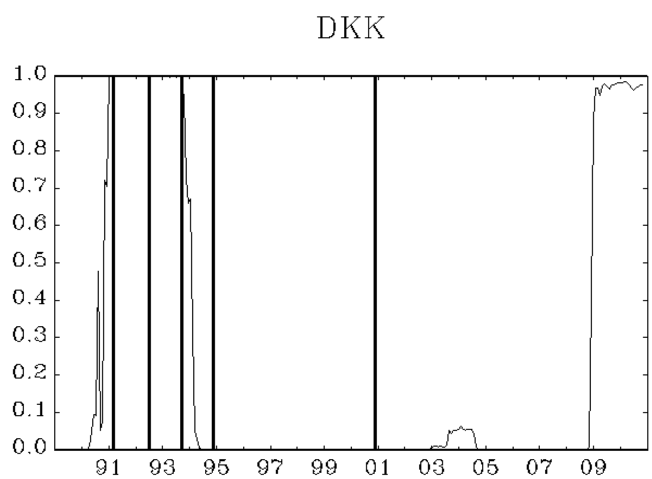
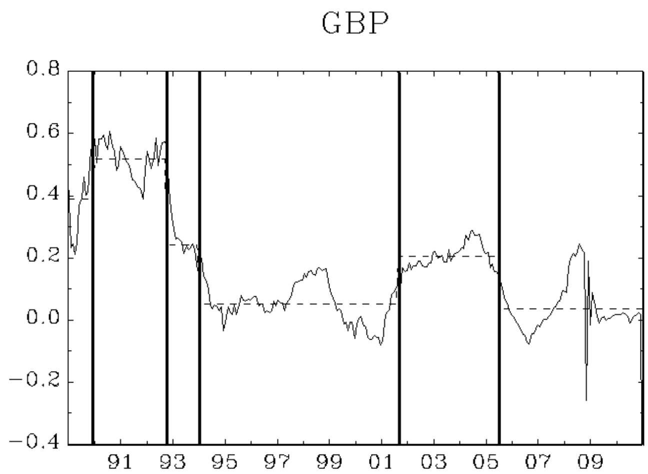


FIGURE 2. (CONT'D)



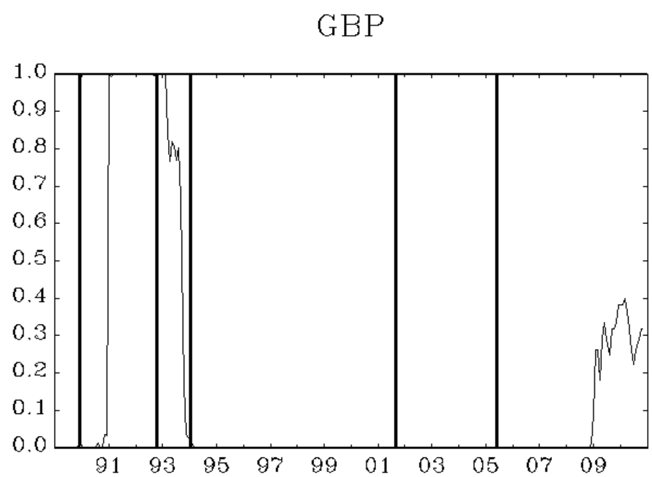
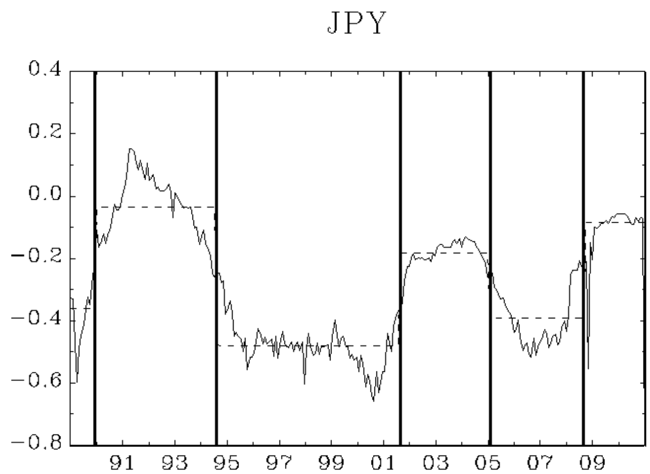


FIGURE 2. (CONT'D)



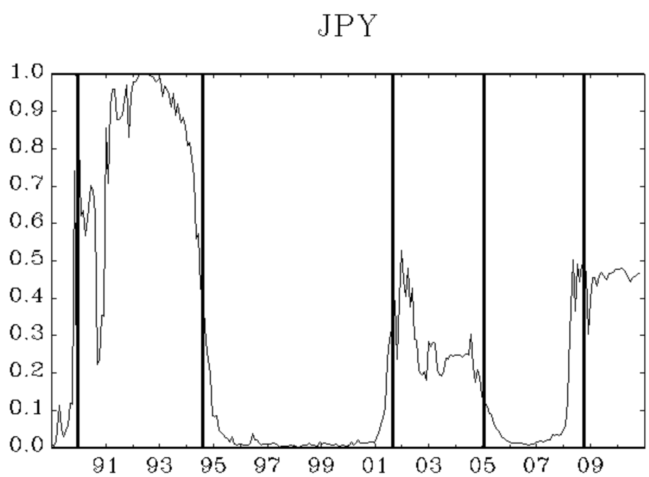
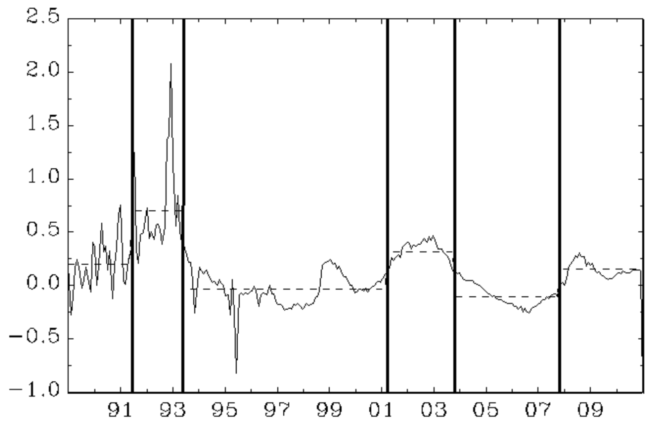


FIGURE 2. (CONT'D)

NOK



NOK

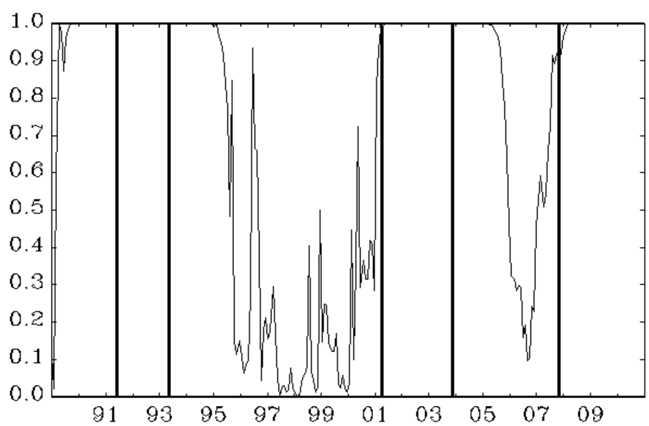


FIGURE 2. (CONT'D)