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Does Ex post *uncovered interest differential reflect the degrees of capital mobility?*

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This paper examines whether *ex post* uncovered interest differential between the US and the UK reflects the degrees of capital mobility over the time period 1973–92 by using GMM, GARCH and Kalman filter methods. The empirical results, however, do not support the hypothesis that the magnitude of the absolute deviation from UIP or the conditional variance of the deviation becomes smaller as the degrees of capital mobility increases.

I. INTRODUCTION

Over the past two decades, world economies have experienced a continuing process of growing financial flows and financial market integration. Reflecting the remarkable speed of integration of financial markets, a number of papers concerning the measurement of capital mobility have been published.

However, it is hard to locate a paper which addresses the following question: if the absolute mean of and volatility of the *ex post* deviation from uncovered interest parity (UIP) have been increased, then does this prove that financial markets have not been integrated? And why does it matter?

In order to answer these questions, let us first look at the component of the *ex post* uncovered interest differential (UD). The deviation from the *ex post* UIP can be divided into three detailed parts:

$$(s_{t+k} - s_t)/s_t -_k r_t +_k r_t^* = (s_{t+k} - E_t s_{t+k})/s_t + E_t(s_{t+k} -_k f_t)/s_t\{(_k f_t - s_t)/s_t -_k r_t +_k r_t*\} \quad (1)$$

where $_kf_t$ is the forward exchange rate at date t for delivery at date $t + k$, s_t is the spot exchange rate, and $_kr_t$ and $_kr_t^*$ refer to the k-period nominal euro-domestic and euro-foreign currency rates, respectively. The third term is called external covered interest differential by Frenkel and Levich (1975, 1977).

Frankel (1993) shows that the external covered interest differential has decreased as the degrees of capital mobility has increased. Thus, if the *ex post* UD reflects the degrees of capital mobility, then it implies that the sum of the risk premium and rational expectation error may diminish over time since most researchers believe that the interdependence of world financial markets has increased.

The common test of UIP is conducted in the following form:

$$(s_{t+k} - s_t)/s_t = a + b(_k r_t -_k r_t^*) + \varepsilon_{t+k} \quad (2)$$

where the error term ε_{t+k} contains the rational expectation error. If the rational expectation hypothesis holds and two financial markets are perfectly integrated, then the estimate of a and b must be equal to zero and one, respectively. If the two markets are not integrated at all, the estimate of b must be zero. Thus, if the degrees of capital mobility at the first subsample is higher than those at the second one, the estimate of b in the first subsample must be lower than that in the second one. In more general terms, b can be time-varying.

If UIP is a proper measure of perfect capital mobility and the coefficient of b is time-varying, then the unbiasedness hypothesis in the foreign exchange markets, which the forward exchange rate is the unbiased predictor of the future spot exchange rate, had better be re-examined. Considering that covered interest parity must hold exactly by an arbitrage condition and that b is time-varying, we can rewrite the regression equation in Equation 2 as follows:

$$y_t = a + \bar{\beta}x_t + (b_t - \bar{\beta})x_t + \varepsilon_{t+k} \quad (3)$$

where $y_t = (s_{t+k} - s_t)/s_t$ and $x_t = (_kf_t - s_t)/s_t$. Here, the parameter of the coefficient on x_t is presumed to evolve over time according to[1]

[1] There can be an alternative specification of the time-varying coefficient model such as the random walk model. If $\bar{\beta}$ is equal to zero, which means no capital mobility, and b_t diverges over time, then the specification of the random walk can be considered. In order to account for the possibility that the true specification of b_t is the random walk, we estimated the nonstationary state space model. However, the empirical results in this paper did not much change according to the specifications. To conserve space, the results for the random walk are not presented in tabular form, but are available from the author.

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$$(b_{t+1} - \bar{\beta}) = \rho(b_t - \bar{\beta}) + \eta_{t+1} \quad (4)$$

If the absolute value of ρ is less than one, then $\bar{\beta}$ can be interpreted as the steady-state value for the coefficient. The fixed coefficient model ignores the third time-varying term in RHS; the residual in the fixed coefficient model consists of ε_{t+k} and $(b_t - \bar{\beta})x_t$. Since the explanatory variable x_t in the fixed coefficient model is contemporaneously correlated with the residual, the ordinary least squares (OLS) estimator of $\bar{\beta}$ in the fixed coefficient model cannot be unbiased in the small sample.

If the absolute deviation from UIP and the estimate of b are not close to zero and one, respectively, then we have to ask whether UIP is a proper measure of perfect capital mobility.

II. ESTIMATION MODELS

Basic statistics: matching moments

There are at least three possible ways to test whether the deviation from UIP reflects the degrees of capital mobility. The first testing method, which is the most commonly used, divides the sample into at least two subsamples and estimates the basic statistics of the deviation from UIP in each subsample. As Frankel (1993) suggests, the absolute magnitude of the mean or variability of the deviation from UIP can be thought of as the existence of significant barriers to integration of international financial markets.

To estimate the means and variances and to know their statistical significance together, generalized method of moments (GMM) can be used. Let $Z = [\mathrm{E}(|z|), \mathrm{Var}(z)]'$ where $\mathrm{E}(\cdot)$ and $\mathrm{Var}(\cdot)$ refer to the mean and variance, and $z = (s_{t+k} - s_t)/s_t -_k r_t +_k r_t^*$, then its absolute mean and variance can be estimated by minimizing the quadratic distance between the sample moments Z_T and theoretical moments Z.

However, the problem with the first method is that one must know the breaking time of the sample. If the breaking time is unknown, then the conditional variance of the *ex post* UD can be estimated by the generalized autoregressive conditional heteroscedasticity (GARCH) estimation method.

GARCH(1,1) model

The second method calculates the conditional variance of UD and examines whether its conditional variance decreases over time. To obtain its conditional variance, we construct the following GARCH(1,1) model:

$$z_t = \delta z_{t-1} + u_t, u_t - N(0, h_t) \quad (5)$$

where

$$h_t = a_1 + a_2 h_{t-1} + a_3 u_{t-1}^2 \quad (6)$$

Stationary conditions for the above GARCH(1,1) model are as follows:

$$-1 < \gamma < 1 \;\; a_1 > 0 \;\; a_2 + a_3 < 1 \;\; a_2 \geq 0 \;\; a_3 \geq 0 \quad (7)$$

The above specification gives the following benefit; we can obtain the conditional variance, h_t, which represents systematic changes in the variability of disturbances which underlie deviations so that we do not need to split the sample.

If the departures from UIP reflect the degrees of linkage between the two financial markets, then the changing degree of capital mobility can be represented by the underlying pattern of conditional heteroscedasticity in disturbances to interest rate parities.

Kalman filter model

The third method estimates the time-varying coefficient of the forward premium in Equation 3. If the regression errors ε_{t+1} in Equation 3 and η_{t+1} are assumed that

$$\begin{pmatrix} \varepsilon_{t+1} \\ \eta_{t+1} \end{pmatrix} \sim N\left(0, \sum\right) \qquad \sum = \begin{pmatrix} Q & 0 \\ 0 & R \end{pmatrix} \quad (8)$$

then we can rewrite Equations 3 and 4 as a state space model with state vector $(b_t - \bar{\beta})$.

III. ESTIMATION RESULTS

All of the data were taken from Harris Bank *Foreign Exchange Weekly Review*. The Harris Bank data are samplings of every Friday, thus we took the data of the last Friday of every month. All spot and one-month forward rates are bid rates and one-month euro-dollar and euro-pound rates are used for the rates of return on the domestic and foreign assets.

In order to know whether the absolute mean of and variance of UD have a tendency to decrease, we construct three subsamples. The first subsample starts from 1973:09 and ends to 1978:12, since Margaret Thatcher removed capital controls in 1979; the second subsample ends at 1984:12; and the third sample ends at 1992:12. The absolute mean of and variance of UD in each subsample are estimated by GMM, and their estimates are reported in Table 1.

The estimation results seem to be disappointing. Both estimates of the variance and absolute mean have a tendency

Table 1. *GMM estimate of the deviation from UIP*
Notation: $z = (s_{t+k} - s_t)/s_t -_k r_t +_k r_t^*$

Subsample	*Var*(z)	*E*($\lvert z \rvert$)	Sample size	NW's lag
73:09–78:12	7.711	2.136	64	3
	(9.064)	(1.585)		
79.01–84:12	9.884	2.603	72	3
	(9.657)	(1.374)		
85:01–92:12	16.847	3.217	100	4
	(25.010)	(1.833)		

Note: Standard errors are in parentheses. $\mathrm{E}(\cdot)$ and $\mathrm{Var}(\cdot)$ refer to mean and variance, respectively. NW refers to Newey and West (1987). The number of Newey–West lag(q) chosen is based on the rule of thumb suggested by Schwert (1987). The rule of thumb is $q = \int[4(T/100^{\frac{1}{4}})]$ where $\int[\cdot]$ stands for integer number in $[\cdot]$.

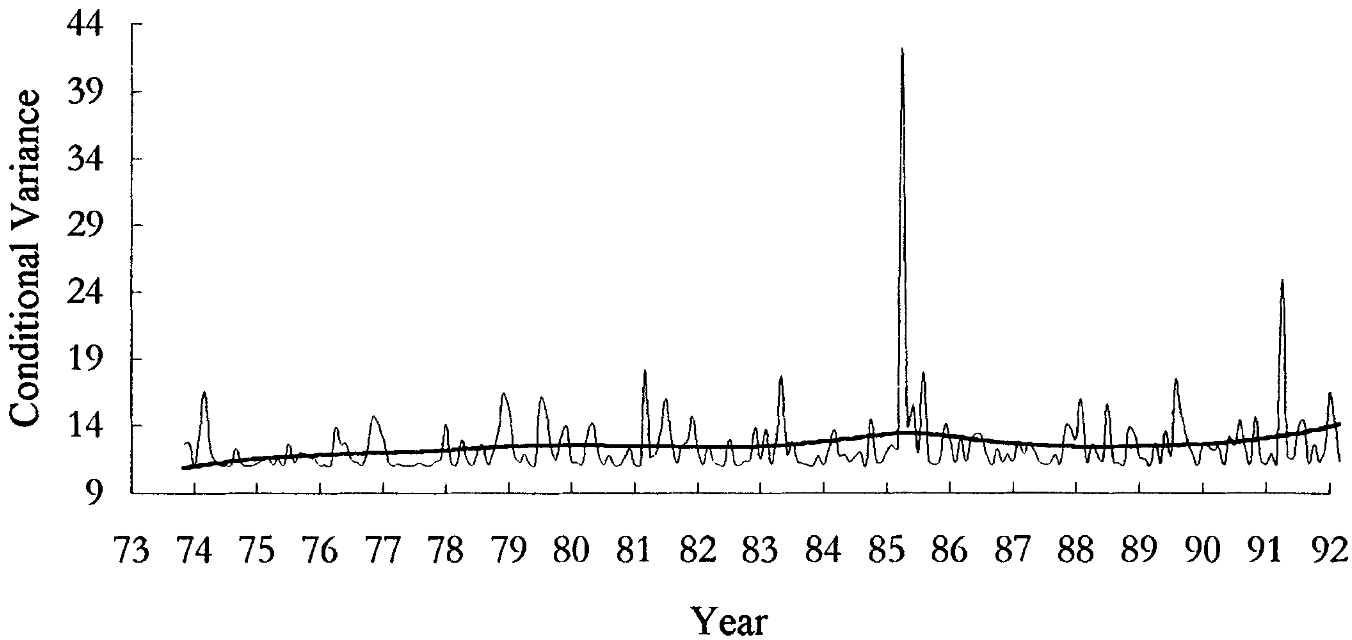

Fig. 1. *Conditional variance of the deviation from UIP. The solid line is the conditional variance of the deviation from UIP and the heavy solid line is its smoothed value by the Hodrick and Prescott filter*

Table 2. *Estimation results of GARCH(1,1) specification*

Model

$$z_t = \delta z_{t-1} + u_t \qquad u_t - N(0, h_t)$$
$$h_t = a_1 + a_2 h_{t-1} + a_3 u_{t-1}^2$$

Estimates			
a_1	a_2	a_3	γ
10.617	0.119	0.038	0.089
(3.810)	(0.123)	(0.293)	(0.075)

Note: Standard errors are in parentheses.

Table 3. *Estimation of time varying regression: unbiasedness hypothesis*

Model

$$(s_{t+k} - s_t)/s_t = a + \bar{\beta}({}_kf_t - s_t)/s_t + (b_t - \bar{\beta})({}_kf_t - s_t)/s_t + \varepsilon_{t+k}$$
$$(b_{t+1} - \bar{\beta}) = \rho(b_t - \bar{\beta}) + h_{t+1}$$
$$\begin{pmatrix}\varepsilon_{t+1}\\ \eta_{t+1}\end{pmatrix} \sim N(0, S) \qquad S = \begin{pmatrix}Q0\\ 0R\end{pmatrix}$$

Estimates of Kalman filter model				
ρ	Q	R	a	$\bar{\beta}$
0.635	7.527	10.191	−0.676	−2.369
(0.345)	(9.750)	(1.459)	(0.320)	(1.100)
		OLS Estimates		
			−0.546	−1.512
			(0.312)	(0.810)

Note: Standard errors are in parentheses.

to increase, however they are not significantly different from zero. Thus, the empirical results in Table 1 do not sufficiently support the conclusion that UIP is not a proper measure of perfect capital mobility.

Table 2 reports the estimation results of the GARCH(1,1) model. All stationary conditions are satisfied, but the standard errors of estimates are so high that the estimates are not statistically significant. Figure 1 shows the conditional variance of UD. The solid line is the conditional variance h_t and the heavy solid line is the smoothed value of h_t by the Hodrick and Prescott filter. Neither the solid nor the heavy solid line seems to have decreased.

Table 3 reports the estimation results of the Kalman filter model. Except for the estimate of Q, all estimates are significantly different from zeros. The estimate of $\bar{\beta}$ is significantly less than one and is less than the OLS estimate. Thus, we know that the unbiasedness hypothesis does not hold even when the coefficient of the forward premium is time-varying.

Figure 2 plots the time-varying coefficient. Surprisingly, all estimates of b_t are less than one except for seven months out of 231 months. During the 1980s, the correlation between the forward premium and the depreciation rate has always been negative.

Thus, the empirical results do not support that UIP reflects the fact that the interdependence between the financial markets in the UK and the US have been increased.

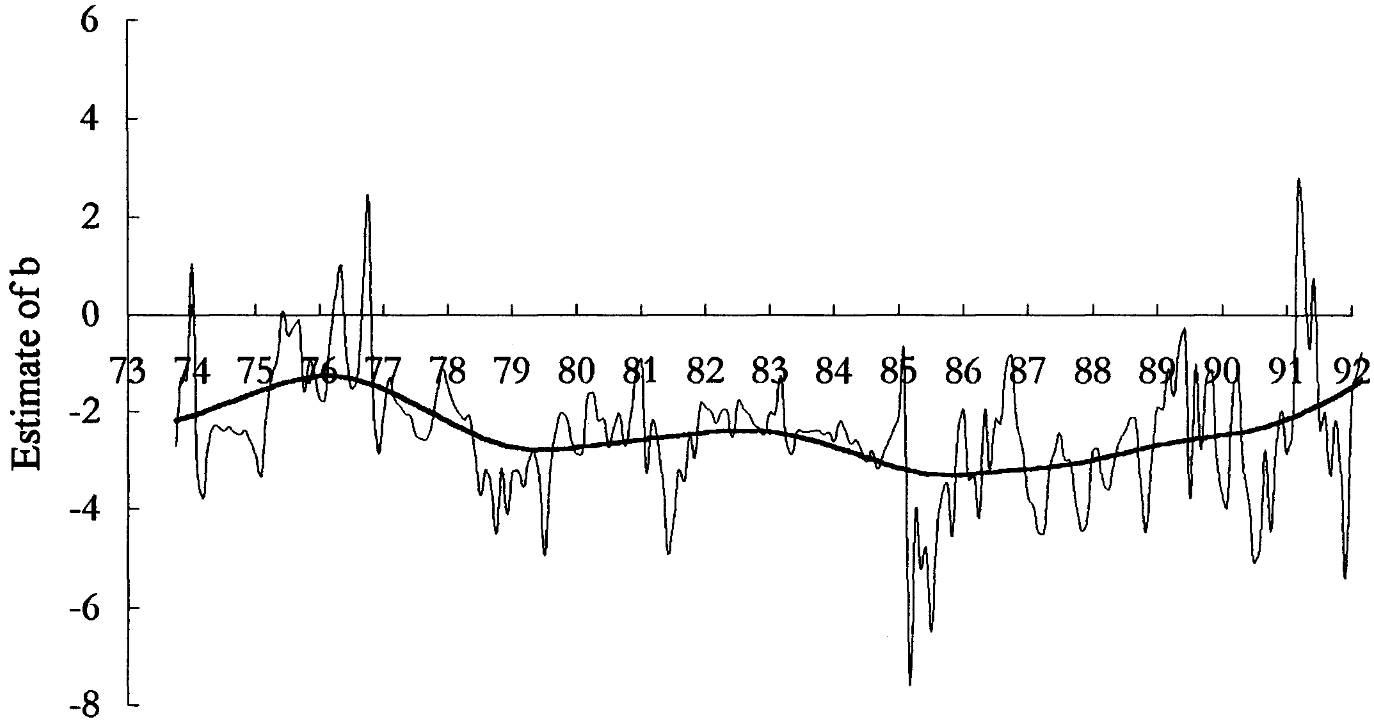

Fig. 2. *Time-varying coefficient: unbiasedness hypothesis. The solid line stands for the time-varying coefficient on the forward premium and the heavy solid line is the smoothed series by the Hodrick and Prescott filter*

Why does the volatility of the sum of the risk premium and the expectation error become larger as the degrees of financial integration increases?

One view is that the volatility of exchange rates becomes higher as the degree of integration of financial markets becomes higher.[2] As regulations and controls on foreign exchange and financial markets have been eliminated, foreign exchange markets become more efficient but its adjustment speed from unexpected exogenous shocks simultaneously becomes faster. Thus, the volatility of the risk premium may be higher as the degrees of capital mobility becomes higher.[3]

Another view is that the rational expectation hypothesis does not hold in the foreign exchange markets.[4] Liu and Maddala (1992) show that the rational expectation error is not stationary with monthly data from the money market services.

However, neither view provides strong theoretical and empirical evidence on how the degrees of capital mobility is related with the risk premium and the rational expectation error.

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[2] See Frankel (1988) for the discussion of the degree of capital mobility and exchange rate volatility.
[3] Cheung (1993) reports that the estimate of the correlation between the risk premium and the rational expectation error between the US and the UK over the time period 1973:07–1987:12 is significantly negative. This implies that the volatility of the sum of the risk premium and the rational expectation error may decrease depending on the value of the covariance between the two as the degrees of financial integration increases.
[4] For an example, see Frankel and Rose (1995).

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APPENDIX: SUPPLEMENTARY TABLES AND FIGURES

Table A1. *Estimation of time varying regression: UIP*

Model

$$(s_{t+k} - s_t)/s_t = a + \bar{\beta}({}_k r_t - {}_k r_t^*) + (b_t - \bar{\beta})({}_k r_t - {}_k r_t^*) + \varepsilon_{t+k}$$

$$(b_{t+1} - \bar{\beta}) = \rho(b_t - \bar{\beta}) + \eta_{t+1}$$

$$\begin{pmatrix}\varepsilon_{t+1}\\ \eta_{t+1}\end{pmatrix} \sim N(0,S) \qquad S = \begin{pmatrix}Q & 0\\ 0 & R\end{pmatrix}$$

Estimates of Kalman filter model				
ρ	Q	R	a	$\bar{\beta}$
0.495	14.067	9.4941	−0.666	−2.398
(0.318)	(11.616)	(1.413)	(0.307)	(1.077)
OLS Estimates				
			−0.487	−1.320
			(0.315)	(0.848)

Note: Standard errors are in parentheses.

Table A2. *Time varying regressions: unbiasedness hypothesis: random walk without a drift*

Model

$$(s_{t+k} - s_t)/s_t = a + b_t({}_k f_t - s_t)/st + \varepsilon_{t+k}$$

$$b_{t+1} = b_t + h_{t+1}$$

$$\begin{pmatrix}\varepsilon_{t+1}\\ \eta_{t+1}\end{pmatrix} \sim N(0,S) \qquad S = \begin{pmatrix}Q & 0\\ 0 & R\end{pmatrix}$$

Estimates			
b_0	Q	R	a
−0.742	0.183	11.269	−1.562
(0.317)	(0.205)	(1.084)	(1.855)

Note: Standard errors are in parentheses. Nonstationary state space models have been initialized by taking the initial value of b_0 to be an unknown constant. Thus, b_0 becomes a nuisance parameter and P_0 is set to zero.

Table A3. *Time varying regressions: UIP: random walk without a drift*

Model

$$(s_{t+k} - s_t)/s_t = a + b_t({}_k r_t - {}_k r_t^*) + \varepsilon_{t+k}$$

$$b_{t+1} = b_t + h_{t+1}$$

$$\begin{pmatrix}\varepsilon_{t+1}\\ \eta_{t+1}\end{pmatrix} \sim N(0,S) \qquad S = \begin{pmatrix}Q & 0\\ 0 & R\end{pmatrix}$$

Estimates			
b_0	Q	R	a
−0.713	0.156	11.321	−1.341
(0.318)	(0.183)	(1.089)	(1.757)

Note: Standard errors are in parentheses. Nonstationary state space models have been initialized by taking the initial value of b_0 to be an unknown constant. Thus, b_0 becomes a nuisance parameter and P_0 is set to zero.

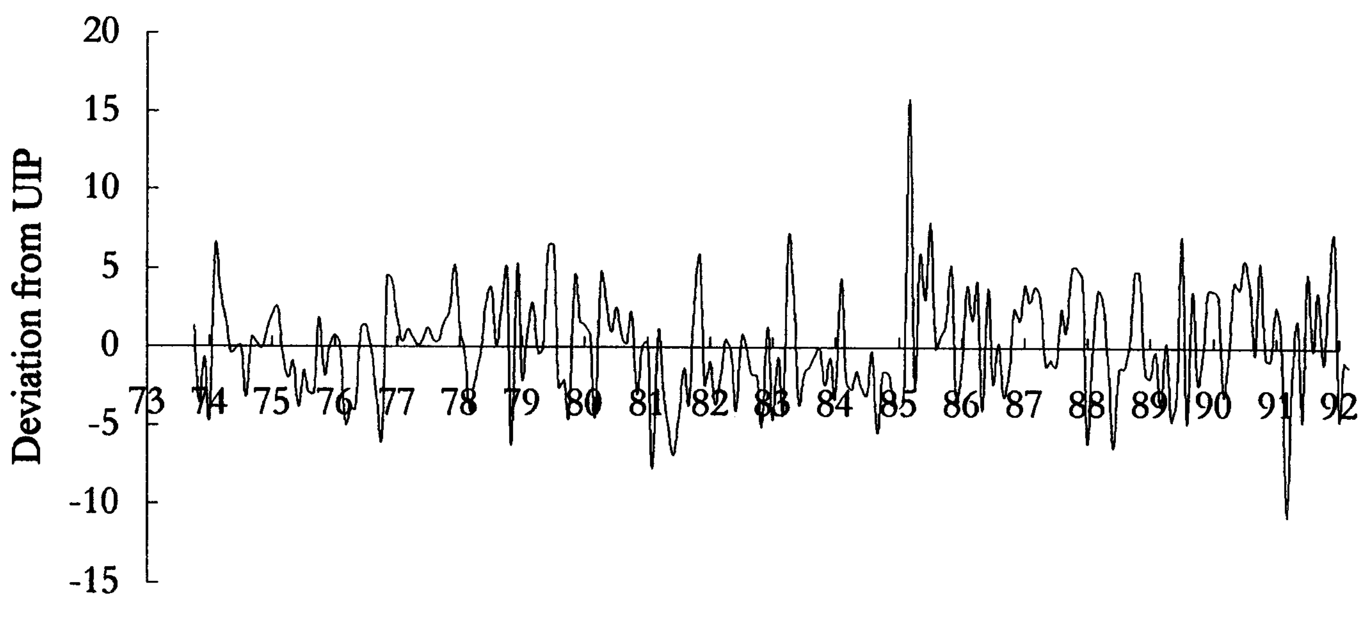

Fig. A1 *Deviation from* ex post *uncovered interest parity*

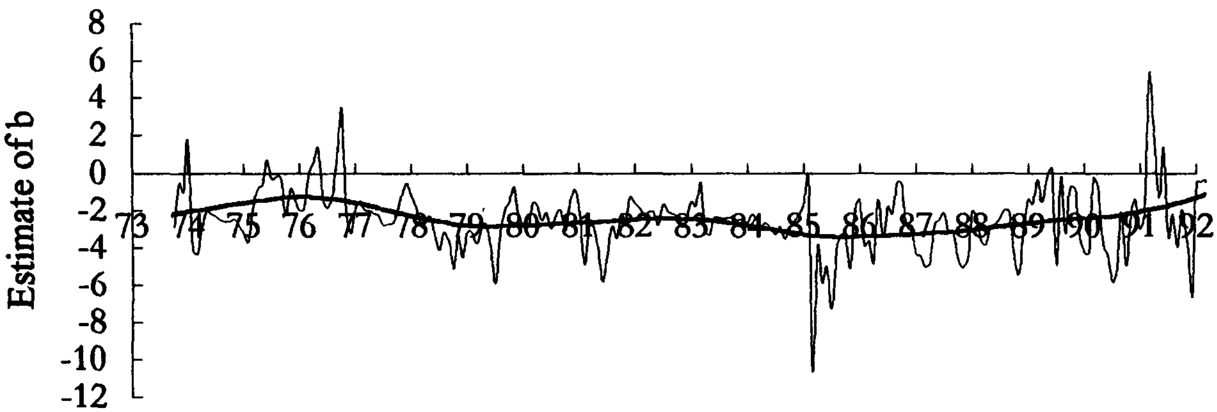

Fig. A2. *Time-varying coefficient: uncovered interest parity. The solid line stands for the time-varying coefficient on interest rate differential and the heavy solid line is the smoothed series by the Hodrick and Prescott filter*

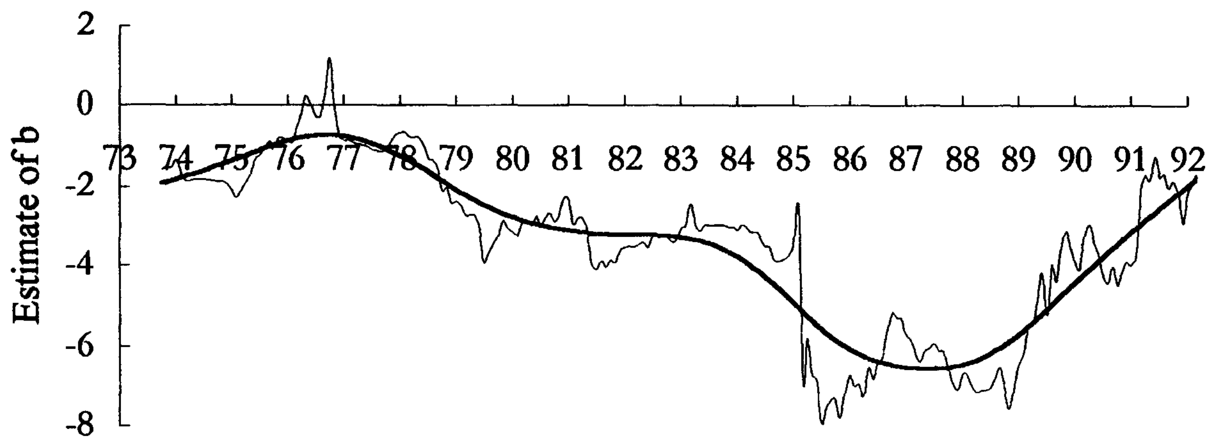

Fig. A3.
Time-varying coefficient: unbiasedness hypothesis: when the coefficient follows a random walk without a drift term. The solid line stands for the time-varying coefficient on interest rate differential and the heavy solid line is the smoothed series by the Hodrick and Prescott filter

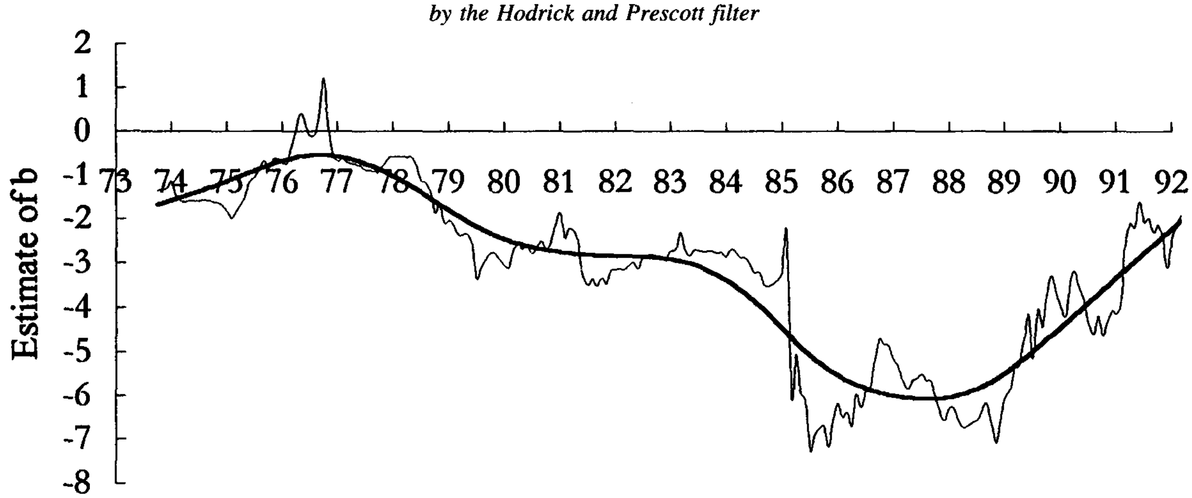

Fig. A4. *Time-varying coefficient: UIP: when the coefficient follows a random walk without a drift term. The solid line stands for the time-varying coefficient on interest rate differential and the heavy solid line is the smoothed series by the Hodrick and Prescott filter*