Covered Interest Parity in the Yen Forward Market: New Insights from Threshold Non-Linear Dynamics

Jonathan A. Batten (HKUST)
Wai-Sum Chan (CUHK)
Hon-Lun Chung (HKPU)
Peter G. Szilagyi (Cambridge)

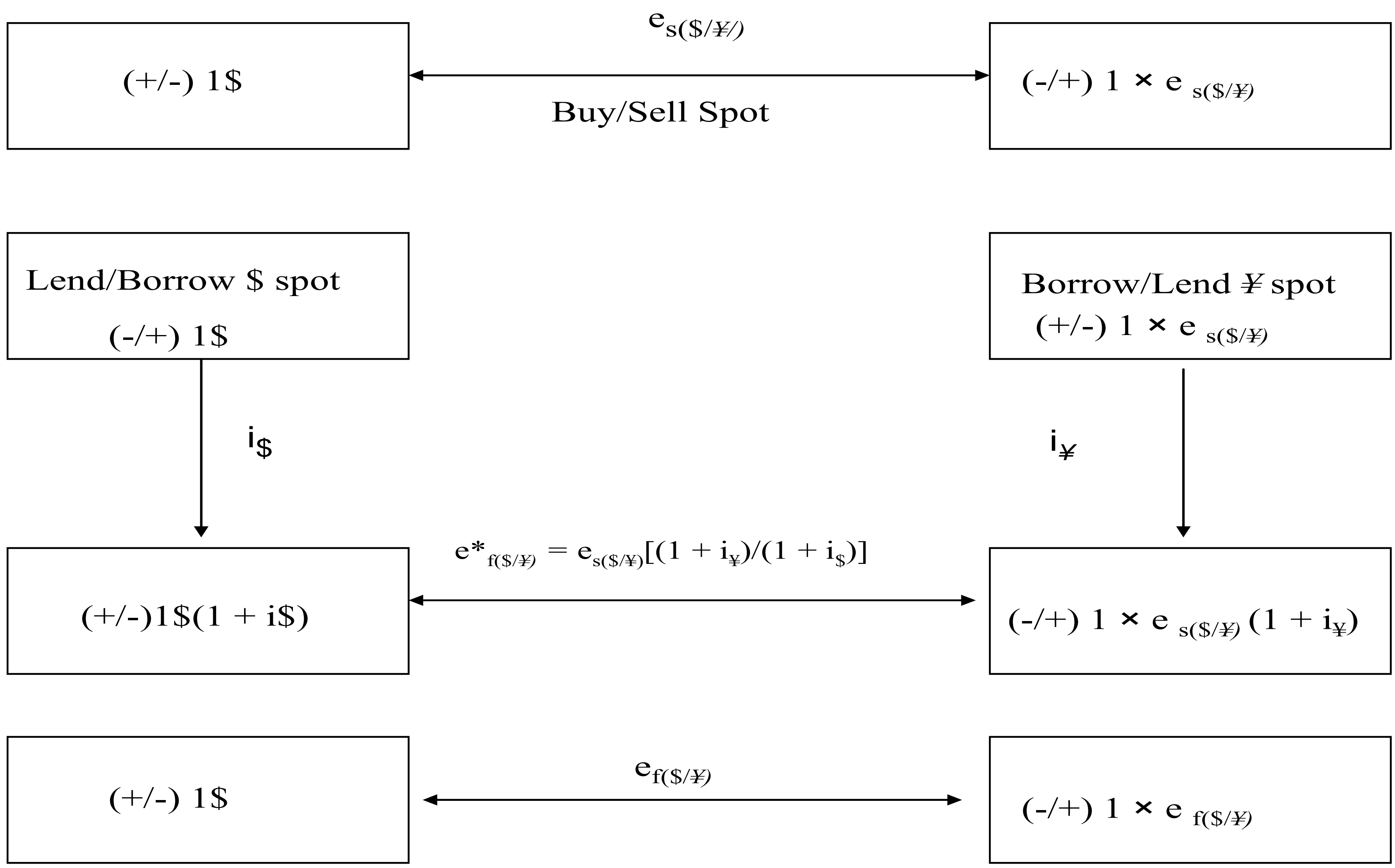
CIP and BTAR Models

Background

- A fundamental assumption in financial economics is that equilibrium prices exist between spot and forward exchange rates and interest rate markets
- Covered interest parity (CIP) arbitrage ensures that these equilibrium prices are maintained. However, CIP is complex and difficult to execute, and institutional factors may create distortions in pricing
- We investigate the complexity of CIP, its bidirectionality, and the economic incentives to shift between currencies
- To do so, we use recent innovations in threshold dynamic modelling

CIP and BTAR Models

The CIP Arbitrage Process is Bidirectional and Driven by Home or Foreign Country Funding Costs



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Motivation

- It is well known that
  - a transaction band – expressed in bps – exists around the equilibrium (parity price)
    - *due credit constraints, liquidity factors, trading costs, taxes etc (Eaton and Turnovsky, 1984; Taylor, 1989; Strobel, 2001; Peel and Taylor, 2002)*
  - size of the potential arbitrage varies with maturity and over time
    - *persistent deviations in longer maturities (Popper 1993)*
  - direction of the arbitrage also changes based on credit access in domestic or foreign currency (Poitras, 1988)
- CIP arbitrage used by banks and large multinationals, although anecdotal evidence shows that opportunities have diminished in recent years (Batten and Szilagyi, 2010)

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Motivation

- While these previous findings remain consistent with theory, it is clear that the CIP relation exhibits a more complex and dynamic structure than previously thought
- Beyond the size and direction of arbitrage, **what is the role of volatility**?
  - it facilitates the emergence of arbitrage opportunities
  - but it also hinders the execution of complex arbitrage
- Given its role as a price link between money and FX markets, and as a vehicle for profit taking, it is critical that the CIP relation be further examined

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What we do

- We apply recent innovations in threshold dynamic modeling to those used by Taylor (1989) and Balke and Wohar (1998) to investigate the dynamic nature of the pricing band around the CIP arbitrage
- We use a Bivariate Threshold AutoRegressive (BTAR) model, where the bivariate pair is the implied and actual forward rates and the threshold value is the difference between the two
- The BTAR model helps identify 3 specific regimes, which are linked to the direction of arbitrage:
  - (i) white noise around the equilibrium, then
  - funding in either (ii) local or (iii) foreign currency (investing in the opposite)

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Advantages of BTAR

1. It provides an exact measure of the economic incentive for a portfolio investor to arbitrage two financial instruments
   – *the forward and the implied forward of equivalent maturity*

   This measure (the "*threshold*" or "*critical*" value) may be interpreted as the hidden cost necessary for financial market participants to shift the arbitrage between investing/borrowing in one currency versus another

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Advantages of BTAR

2. The threshold values can be used to anticipate the change in the direction of arbitrage
   – this will allow traders to be more cautious in managing risk and help policymakers and central banks fine tune monetary policies (e.g. when intervention is linked to volatility smoothing)

3. The threshold values can be expressed in terms of exchange rate “bps”
   – this is a number that can be easily understood and interpreted by financial markets as the economic incentive to adjust the CIP portfolio

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Why USD-JPY

We investigate CIP in the spot and forward USD to JPY market

1.The Bank for International Settlements (BIS, 2008) reports that the USD-JPY currency pair accounts for 20% of daily turnover in spot and forward markets

- the USD-EUR pair accounts for 30%, but there is no long time series available

CIP and BTAR Models

Why USD-JPY

2. The USD-JPY has particular economic appeal
   - US-based financial institutions enjoy an advantage in domestic deposit and securities markets
   - However, Japanese banks have a potential home currency advantage through an extensive deposit base and historical regulatory hurdles that limit foreign bank access
   - The combined actions of these groups of institutions presuppose a more dynamic and complex 2-way CIP relation than observed in other markets
     - *the USD-JPY spot and forward exchange rates are known to have complex dynamics (Elliott and Ito, 1999)*

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Data – consistent prices (credit, time of day etc)

- We use London interbank spot and forward forex midrates on USD-JPY, and Euromarket USD and JPY LIBOR interest rates with 3 and 6-month maturities
  - same credit ratings and limited sovereign risk on Euromarket deposits
- At daily close of trading from 11-Oct-1983 to 23-Apr-2008
  - original series from 1-Jan-1983 but some incomplete series for the forward and money market rates
  - we end the sample before the main effects of the financial crisis

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Calculating equilibrium

- With respect to CIP and following Taylor (1989), Popper (1993) etc., we express the relation between spot (e_s) and forward (e_f) exchange rates and the underlying USD and JPY interest rates $i^{\$}$ and $i^{¥}$ for maturity m as

$$(1 + i^{\$}_m) = e_s / e_{fm} (1 + i^{¥}_m)$$

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Calculating residuals

- The residuals δ_m are calculated between:
  - the actual forward rate e_f quoted at t_0
  - the estimated forward rate e_{fm}* for maturity m at t_0 based on the interest rate differentials
- Specifically, the estimated forward rate is

$$e_{fm}^{*} = e_s (1+i^{¥}_m) / (1 + i^{\$}_m)$$

and therefore

$$\delta_m = e_{fm} - e_{fm}^{*}$$
$$= e_{fm} - e_s (1+i^{¥}_m) / (1 + i^{\$}_m)$$

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Definition of BTAR

We consider a bivariate time series along Tsay (1998) and Chan and Cheung (2005), where $Z_t = (z_{1t}, z_{2t})'$ with $z_{1t} = e_{fm}$ and $z_{2t} = e_{fm}{}^*$. A k-regime BTAR ($d; p_1, \ldots, p_k$) model is defined as

$$\mathbf{Z}_t = \begin{cases} \boldsymbol{\omega}_0^{(1)} + \sum_{j=1}^{p_1} \boldsymbol{\Phi}_j^{(1)} \mathbf{Z}_{t-j} + \mathbf{a}_t^{(1)}, \text{ if } y_{t-d} \le r_1 \\ \boldsymbol{\omega}_0^{(2)} + \sum_{j=1}^{p_2} \boldsymbol{\Phi}_j^{(2)} \overset{\boldsymbol{\omega}}{\mathbf{Z}}_{t-j} + \mathbf{a}_t^{(2)}, \text{ if } r_1 < y_{t-d} \le r_2 \\ \ldots \\ \boldsymbol{\omega}_0^{(k)} + \sum_{j=1}^{p_k} \boldsymbol{\Phi}_j^{(k)} \mathbf{Z}_{t-j} + \mathbf{a}_t^{(k)}, \text{ if } r_{k-1} < y_{t-d} \end{cases}$$

with delay parameter d, autoregressive order in ith regime p_i, (2x1)-dimensional constant vectors $\boldsymbol{\omega}_0^{(\mathrm{i})}$, (2x2)-dimensional matrix parameters $\Phi_j^{(i)}$ for $i = 1,\ldots,k$. The threshold parameters satisfy $-\infty = r_0 < r_1 < r_2 < \ldots < r_{k-1} < r_k = \infty$.

CIP and BTAR Models

Descriptive statistics for BTAR variables

$y_{1t} = ln(e_{f,m,t}) - ln(e_{f,m,t-1})$ and $y_{2t} = ln(e_{f,m,t}{}^*) - ln(e_{f,m,t-1}{}^*)$ are first differences

$z_t = ln(e_{fmt}) - ln(e_{fmt}{}^*)$ is the threshold variable

Variable	Mean	St.dev.	Min	Max	Skewness	Kurtosis
y1_6m	-0.00013	0.00664	-0.05468	0.03421	-0.54	4.74
y2_6m	-0.00013	0.00663	-0.05518	0.03481	-0.53	4.81
zt_6m	-0.00041	0.00109	-0.01032	0.01715	2.06	48.72
y1_3m	-0.00013	0.00662	-0.05511	0.03423	-0.55	4.78
y2_3m	-0.00013	0.00662	-0.05643	0.03462	-0.53	4.74
zt_3m	-0.00025	0.00098	-0.01245	0.01608	1.24	52.68

BTAR results for the 6-month CIP

(a) The first regime ($k = 1, p_1 = 9$), $n_1 = 627$ when $z_{t-2} \leq -0.001067$

$$\begin{array}{lcccccc}
\text{Lag}(j) & 0 & 1 & 2 & 3 & 4 & 5 \\
& \begin{pmatrix} 0.00 \\ 0.00 \end{pmatrix} & \begin{pmatrix} -0.36^* & 0.43^* \\ 0.44^* & -0.37 \end{pmatrix} & \begin{pmatrix} -0.31 & 0.28 \\ 0.43 & -0.47 \end{pmatrix} & \begin{pmatrix} -0.41 & 0.41 \\ 0.21 & -0.20 \end{pmatrix} & \begin{pmatrix} -0.62^* & 0.58^* \\ -0.12 & 0.09 \end{pmatrix} & \begin{pmatrix} -0.58 & 0.63^* \\ -0.21 & 0.25 \end{pmatrix} \\
\text{Lag}(j) & & 6 & 7 & 8 & 9 & \\
& & \begin{pmatrix} -0.49 & 0.39 \\ -0.17 & 0.06 \end{pmatrix} & \begin{pmatrix} -0.07 & 0.07 \\ 0.21 & -0.22 \end{pmatrix} & \begin{pmatrix} 0.00 & 0.00 \\ 0.29 & -0.29 \end{pmatrix} & \begin{pmatrix} 0.59^* & -0.57^* \\ 0.70^* & -0.68^* \end{pmatrix} &
\end{array}$$

(b) The second regime ($k = 2, p_2 = 7$), $n_2 = 5376$ when $-0.001067 < z_{t-2} \leq 0.000250$

$$\begin{array}{lcccccc}
\text{Lag}(j) & 0 & 1 & 2 & 3 & 4 & 5 \\
& \begin{pmatrix} 0.00 \\ 0.00 \end{pmatrix} & \begin{pmatrix} -0.85^* & 0.86^* \\ 0.01 & 0.01 \end{pmatrix} & \begin{pmatrix} -0.09 & 0.11 \\ 0.08 & -0.06 \end{pmatrix} & \begin{pmatrix} -0.20 & 0.20 \\ -0.06 & 0.06 \end{pmatrix} & \begin{pmatrix} -0.11 & 0.12 \\ 0.00 & 0.00 \end{pmatrix} & \begin{pmatrix} -0.24 & 0.22 \\ -0.18 & 0.16 \end{pmatrix} \\
\text{Lag}(j) & & 6 & 7 & & & \\
& & \begin{pmatrix} -0.28^* & 0.29^* \\ -0.23 & 0.24^* \end{pmatrix} & \begin{pmatrix} -0.23^* & 0.25^* \\ -0.20^* & 0.22^* \end{pmatrix} & & &
\end{array}$$

(c) The third regime ($k = 3, p_3 = 3$), $n_3 = 385$ when $z_{t-2} > 0.000250$

$$\begin{array}{lcccc}
\text{Lag}(j) & 0 & 1 & 2 & 3 \\
& \begin{pmatrix} 0.00 \\ 0.00 \end{pmatrix} & \begin{pmatrix} -0.89^* & 0.95^* \\ -0.34 & 0.39^* \end{pmatrix} & \begin{pmatrix} -0.61^* & 0.62^* \\ -0.09 & 0.14 \end{pmatrix} & \begin{pmatrix} -0.40^* & 0.46^* \\ -0.16 & 0.20 \end{pmatrix}
\end{array}$$

BTAR Results for the 6-month CIP

We identify 3 regimes for the 6-month series:

- Regime 1exists when $z_{t-2} \leq -0.001067$
- Regime 2 exists when $-0.001067 < z_{t-2} \leq 0.000250$
- Regime 3 exists when $z_{t-2} > 0.000250$

In term of frequencies:

- Regime 1 occupies about 10% of the sample period (626 observations)
- Regime 2 occupies 84% (5,383 observations)
- Regime 3 occurs most infrequently and occupies 6% (385 observations)

BTAR Results for the 3-month CIP

We identify 3 regimes for the 3-month series:

- Regime 1exists when $z_{t-2} \leq -0.000423$
- Regime 2 exists when $-0.000423 < z_{t-2} \leq 0.000167$
- Regime 3 exists when $z_{t-2} > 0.000167$

In term of frequencies:

- Regime 1 occupies about 20% of the sample period (1,310 observations)
- Regime 2 occupies 74% (4,760 observations)
- Regime 3 occurs most infrequently and occupies 5% (325 observations)

ANOVA results

To provide additional economic meaning to the three regimes, we conduct one-way Analysis of Variance (ANOVA) tests on the relationship between the regimes and δ_m

- This comparison has the added advantage of being readily understood in an economic sense given that δ_m is in exchange rate basis points

ANOVA results

For the 6-month series, the average δ_m for the 3 regimes:

- Regime 1: -0.122 (σ = 0.185)
- Regime 2: -0.046 (σ = 0.137)
- Regime 3: -0.011 (σ = 0.188).

The *F-statistic* of difference in the means is 92.7 (p=0.000)

For the 3-month series, the average δ_m for the 3 regimes:

- Regime 1: -0.055 (σ = 0.149)
- Regime 2: -0.026 (σ = 0.111)
- Regime 3: -0.037 (σ = 0.227)

The *F-statistic* of difference in the means is 26.5 (p=0.000)

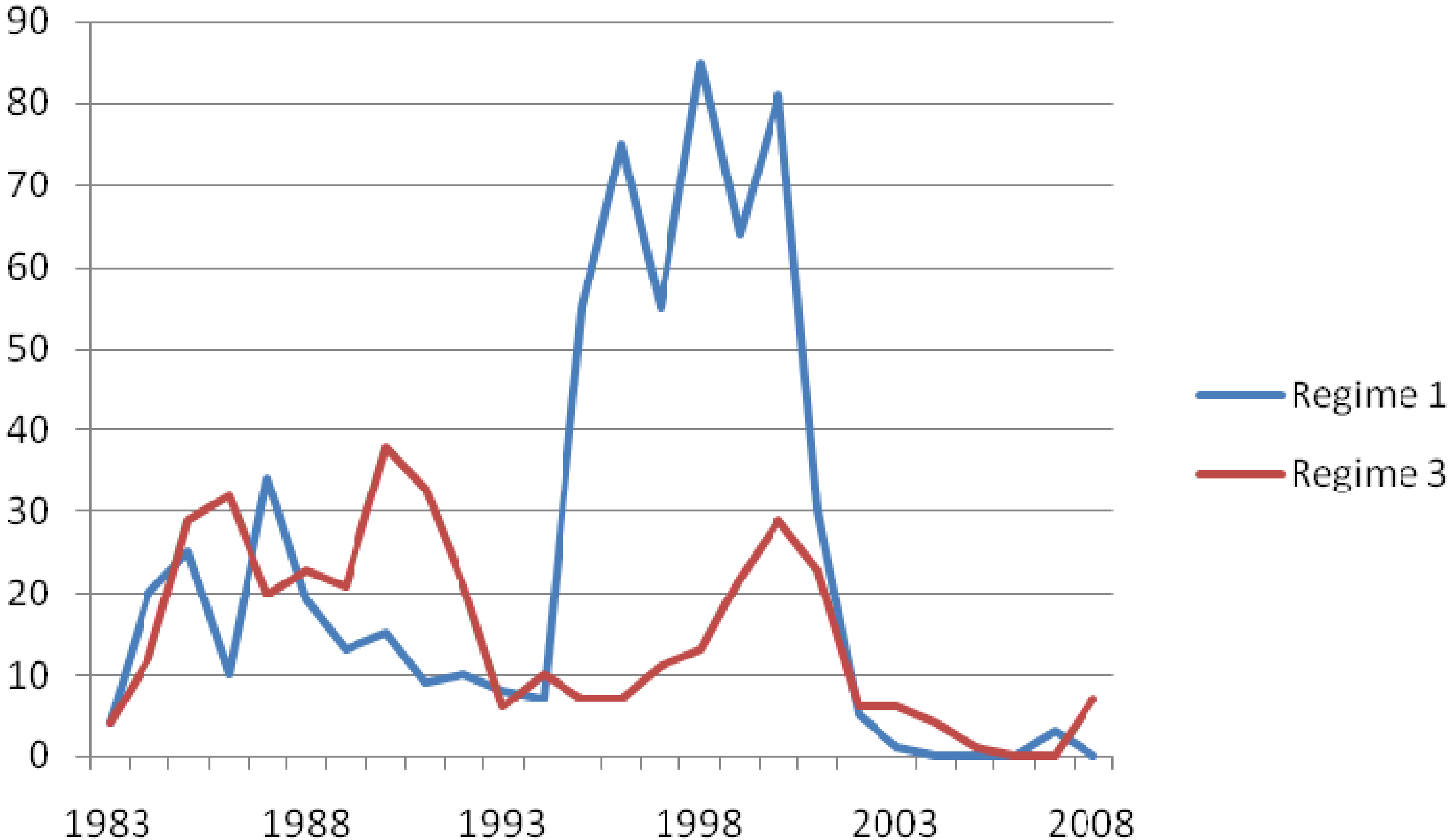
ANOVA results

In both the 3 and 6-month case:

- Regime 2 is by far the most frequent, shows evidence of a transaction band of white noise
- Regime 1 has higher volatility and the most negative residuals, favoring USD borrowers. It offers the greatest potential profit for arbitrageurs, yet arbitrage opportunities persist (breakdown of equilibrium?)
- Regime 3 has the highest volatility but only small negative residuals, possibly favoring JPY borrowers. Arbitrage opportunities do not really persist; result may be driven by market timing issues.

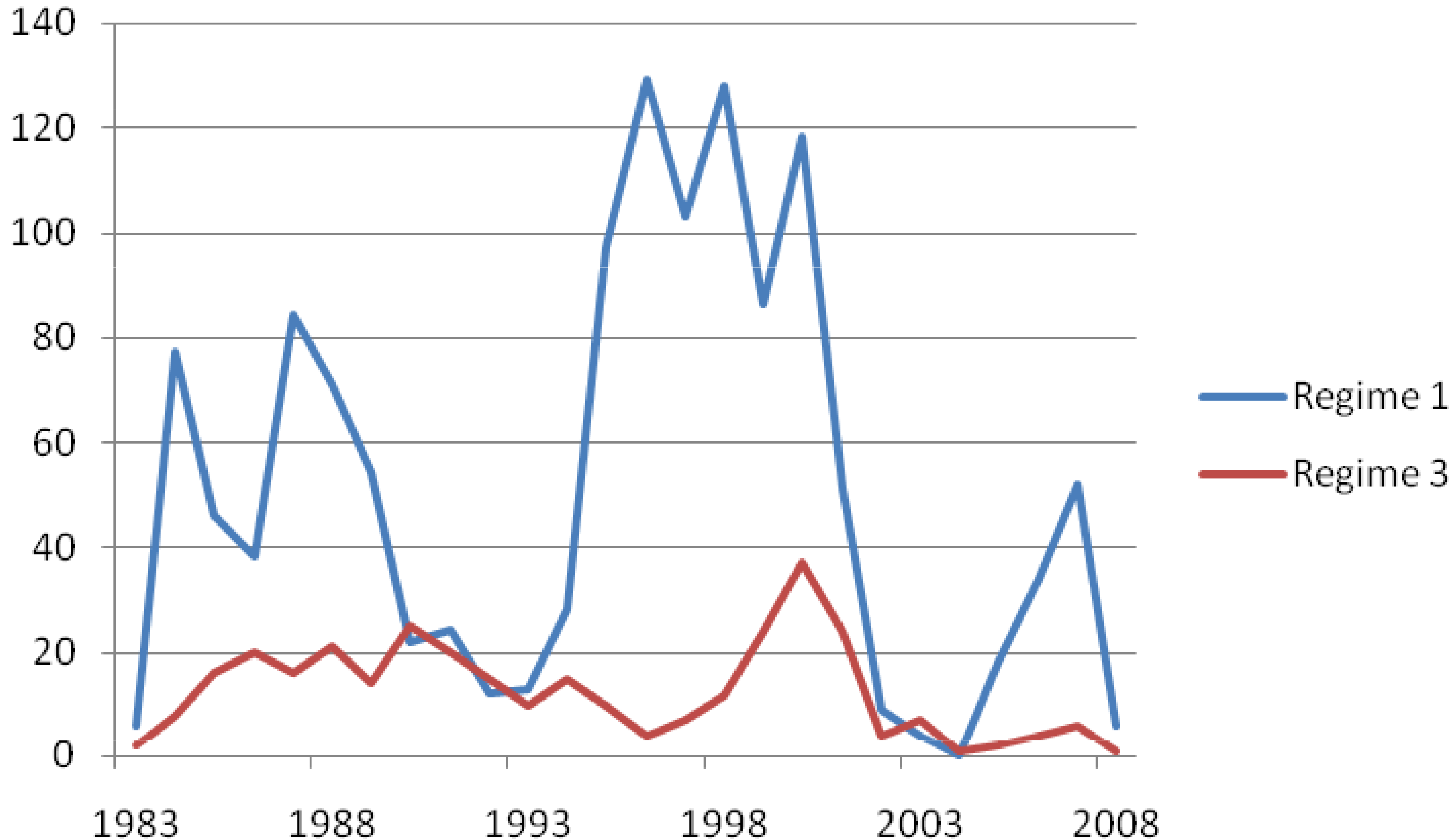
Frequency of regimes over time

6-month USD-JPY



Frequency of regimes over time

3-month USD-JPY



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Conclusions

1. Three regimes are identified in the 3 and 6-month CIP relation, which also coincide with significant differences in frequency.

   Regime 2 is the most frequent in both cases and characterized by the lowest variance.

   The presence of these regimes is consistent with existing theories on the presence of a trading band of white noise around a parity price.

CIP and BTAR Models

Conclusions

2. The lower frequency and most negative values Regime 1 are consistent with studies that highlight the advantage of those with access to USD borrowings in exploiting arbitrage in international markets: the lower spreads are only available to those who can sell USD spot and borrow USD to achieve hedged JPY that can then be invested.

These positions offer the prospect of the greatest economic profit from arbitrage.

CIP and BTAR Models

Conclusions

3. The results confirm the presence of a time-varying transaction band around the parity price that varies with the maturity of the forward contract.

4. Finally, the variance of the average price differs within the three regimes, with Regime 3 being the most volatile. Thus volatility of arbitrage (the difficulty of securing hedged positions immediately) likely affects the ability of those with JPY who would like to undertake reverse arbitrage positions to those holding USD.