A. MEASURING VOLATILITY IN THE HIGH-FREQUENCY SETTING

Typical approach forecasts latent volatility using GARCH or some parametric approach and then uses squared daily returns as proxy for realized volatility to check forecast performance.

Alternative: use sum of intraday returns to estimate daily volatility

* with small measurement error can treat daily volatility as observed
* can use simpler techniques to examine volatility dynamics than when volatility is latent

Consider the following continuous-time logarithmic price process

\[ dp_t = \sigma_t dW_t \]

where \( W_t \) denotes a standard Brownian motion and \( \sigma_t \) is a stationary process.

The corresponding discretely-sampled returns with \( m \) observations per period are

\[ r(m)_t = p_t - p_{t-1}/m = \int_0^{1/m} \sigma_{t-1}/m + \tau dW_{t-1}/m + \tau \]

where \( t \) has units of \( 1/m, 2/m, \ldots \)

* so if interested in 5 minute sampling intervals, then \( m=288 \)
*for one day \( m=1 \)

Assume expected returns equal zero for all \( m \)

Assuming \( \sigma_t \) and \( W_t \) are independent, the variance of \( h \)-period returns are

\[
\sigma^2_{t,h} = \int_0^h \sigma^2_{t+\tau} d\tau
\]

Andersen, Bollerslev, Diebold, & Labys show that

\[
\text{plim}_{m \to \infty} \frac{1}{m} \sum_{j=1}^{mh} (r_{(m),t+j}/m)^2 = \sigma^2_{t,h}
\]

"hence by summing sufficiently many high-frequency discrete time intraday returns one may approximate the integrated volatility arbitrarily well over any horizon"

**Question**
Then why not sample at highest possible frequency?

**Answer**
"microstructure effects" more important at higher frequencies

*non-synchronous quoting or trading for multivariate settings
*infrequent quoting or trading for univariate
*bid-ask bounce

*all create measurement error in approximating true volatilities

Can guide choice of optimal sampling frequency with "volatility signature plot"

plot average realized volatility (arv) against sampling frequency

*as frequency increases, bias increases

*look for highest frequency where volatility stabilizes

ABD&L argue that 5 minutes is OK for JPY/USD and DEM/USD

References

Andersen, Bollerslev, Diebold, & Labys, *series of working papers* see [http://www.ssc.upenn.edu/~diebold/index.html](http://www.ssc.upenn.edu/~diebold/index.html)
B. THE GLOBAL TRANSMISSION OF VOLATILITY IN THE FOREIGN EXCHANGE MARKET

I. Introduction

Own-region volatility persistence (heat wave)

Interregional volatility persistence (meteor shower)


Geographic component in intradaily volatility

Objective: construct and estimate regional volatility models using high-frequency data

Advantage of regional models:

* allow for different news flows or institutional features across regions
* allow unique interrelationships of each region with other regions
* reduce intradaily seasonality in data since focusing on period of peak activity in each region

Staleness adjustment:

* information in earlier regions may become “stale” with time
* discount earlier volatility to account for staleness
II. Volatility Persistence and Regional Components

Why hypothesize that volatility persists across regions?

* Speculative bubbles or bandwagon effects
* Serially correlated public information
* Stochastic response to public information
* Private information revealed slowly over time
* Traders with different models or horizons
* Risk and info. sharing among traders in overlapping regions
III. Data and Geographic Organization of the Market

Reuters FXFX spot rate quotes on DM/$

*Olsen and Associates data

15 minute periodicity

*interpolate between quotes preceding and following each 15 minute point:

\[
q^i_t = 0.5 \left[ 1 - \left( \frac{T_t - \tau_{t-1}}{\tau_{t+1} - \tau_{t-1}} \right) \left( \ln B^i_{t-1} + \ln A^i_{t-1} \right) + \left( 1 - \left( \frac{\tau_{t+1} - T_t}{\tau_{t+1} - \tau_{t-1}} \right) \left( \ln B^i_{t+1} + \ln A^i_{t+1} \right) \right) \right]
\]

\[
dq^i_t*10,000 \text{ for data set}
\]
Regional Definitions:

*Identify by quote frequency (Figure 1) of institutions in countries with >1% of global market turnover

*Hours differ with daylight saving time (Table 1)
<table>
<thead>
<tr>
<th>Sample Period</th>
<th>Asia</th>
<th>Asia-Europe Overlap</th>
<th>Europe</th>
<th>Europe-America Overlap</th>
<th>America</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/28/93-3/28/94 (no DST)</td>
<td>22:00-6:30</td>
<td>6:30-8:00</td>
<td>8:00-12:30</td>
<td>12:30-16:30</td>
<td>16:30-21:00</td>
</tr>
<tr>
<td>3/29/94-4/29/94 (only Eur. DST)</td>
<td>22:00-6:30</td>
<td>6:30-8:00</td>
<td>8:00-12:30</td>
<td>12:30-15:30</td>
<td>15:30-21:00</td>
</tr>
<tr>
<td>4/30/94-4/30/94 (Eur. and Amer. DST)</td>
<td>23:30-6:30</td>
<td>5:30-8:00</td>
<td>8:00-12:30</td>
<td>11:30-15:30</td>
<td>15:30-20:00</td>
</tr>
<tr>
<td>9/29/94-10/29/94 (only Amer. DST)</td>
<td>22:00-6:30</td>
<td>6:30-8:00</td>
<td>8:00-12:30</td>
<td>11:30-16:30</td>
<td>16:30-20:00</td>
</tr>
<tr>
<td>10/30/94-12/20/94 (no DST)</td>
<td>22:00-6:30</td>
<td>6:30-8:00</td>
<td>8:00-12:30</td>
<td>12:30-16:30</td>
<td>16:30-21:00</td>
</tr>
<tr>
<td>3/24/95-4/10/95 (only Eur. DST)</td>
<td>22:00-6:30</td>
<td>6:30-8:00</td>
<td>8:00-12:30</td>
<td>11:30-15:30</td>
<td>15:30-21:00</td>
</tr>
<tr>
<td>4/11/95-4/7/95 (Eur. and Amer. DST)</td>
<td>22:00-6:30</td>
<td>6:30-8:00</td>
<td>8:00-12:30</td>
<td>11:30-15:30</td>
<td>15:30-20:00</td>
</tr>
</tbody>
</table>

The table indicates the GMT of peak trading activity in each region. Regional groupings comprise countries with at least 5% market share of total DMS trade. According to the table: Asia = Australia, Hong Kong, Japan, Singapore; Europe = Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Spain, Sweden, Switzerland, United Kingdom; America = Canada, United States.
IV. Models of Geographic Volatility

Use integrated volatility in order to treat daily volatility as observed rather than latent:

Consider the exchange rate quote \( q \):

\[
 dq_t = \sigma_t dW_t
\]

where \( t \geq 0 \), \( W_t \) denotes a standard Brownian motion, and \( \sigma_t \) is a strictly stationary process corresponding discretely-sampled returns with \( m \) observations per period:

\[
 r_{(m),t} \equiv q_t - q_{t-1/m} = \int_0^{1/m} \sigma_{t-1/m + \tau} dW_{t-1/m + \tau}
\]

\( t=1/m, 2/m, \ldots \)

variance of the \( h \)-period returns, \( r_{(1/h), t+h} \), for \( h > 0 \):

\[
 \sigma_{t,h}^2 \equiv \int_0^h \sigma_{t+\tau}^2 d\tau
\]

realized volatility is consistent (in \( m \)) for the integrated volatility as in:

\[
 \lim_{m \to \infty} \sum_{j=1, \ldots, mh} r_{(m), t+j/m}^2 = \sigma_{t,h}^2.
\]

sum the intraday squared returns from our 15-minute data to create a measure of integrated volatility for each region

- standardize the integrated volatility measures by dividing by the number of 15-minute intervals in each region
- use the logarithms of volatility which are closer to normality and reduce the problem of major outliers

estimate daily volatility for each region as a function of past volatility of the same region as well as of the volatility of the other region

- timing of the other regional volatility measures included on the right-hand-side will differ by region

\[ \sigma_t^2 = A_1 \sigma_{t-1}^2 + \ldots A_p \sigma_{t-p}^2 + Bx_t + \epsilon_t \]

- \( \sigma^2 \) represents a vector containing regional volatility measure
- \( x \) represents a vector of dummy variables for days of major exchange rate events along with a dummy for Mondays and holidays
- five-equation system is estimated using seemingly-unrelated-regressions
TABLE 2

Wald Tests for Own-Region and Inter-Region DM/$ Volatility Persistence

Dependent variables are in columns with independent variables in rows. Regional volatility variables are: AS, Asia; AE, Asia-Europe overlap; EU, Europe; EA, Europe-America overlap; and AM, America. Additional variables in the regressions not reported in the table include a constant, dummy variables for days of major FX events, and dummies for Mondays and holidays. The table reports Wald coefficient tests for blocks of coefficients representing heat waves (own-region volatility persistence) and meteor showers (inter-regional volatility persistence). Chi-square statistics and associated P-values (in parentheses) are reported for each block of coefficients. For each equation, $R^2$ and p-values of Q-statistics for residual autocorrelation are reported for 5 lags (1 week) and 35 lags (7 weeks).

<table>
<thead>
<tr>
<th>Dependent Regions</th>
<th>AS</th>
<th>AE</th>
<th>EU</th>
<th>EA</th>
<th>AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Regions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>29.87</td>
<td>19.55</td>
<td>3.39</td>
<td>9.48</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.18)</td>
<td>(0.01)</td>
<td>(0.86)</td>
</tr>
<tr>
<td>AE</td>
<td>0.12</td>
<td>26.35</td>
<td>26.01</td>
<td>0.72</td>
<td>2.36</td>
</tr>
<tr>
<td></td>
<td>(0.94)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.70)</td>
<td>(0.31)</td>
</tr>
<tr>
<td>EU</td>
<td>27.56</td>
<td>16.91</td>
<td>10.45</td>
<td>2.56</td>
<td>14.42</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.28)</td>
<td>(0.00)</td>
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<tr>
<td>EA</td>
<td>3.64</td>
<td>2.77</td>
<td>14.98</td>
<td>22.10</td>
<td>48.18</td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td>(0.25)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>AM</td>
<td>14.12</td>
<td>4.88</td>
<td>5.48</td>
<td>8.13</td>
<td>8.03</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.09)</td>
<td>(0.06)</td>
<td>(0.02)</td>
<td>(0.02)</td>
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<tr>
<td>$R^2$</td>
<td>0.44</td>
<td>0.46</td>
<td>0.47</td>
<td>0.38</td>
<td>0.50</td>
</tr>
<tr>
<td>p-value, Q(5)</td>
<td>0.25</td>
<td>0.13</td>
<td>0.60</td>
<td>0.18</td>
<td>0.81</td>
</tr>
<tr>
<td>p-value, Q(35)</td>
<td>0.16</td>
<td>0.69</td>
<td>0.88</td>
<td>0.03</td>
<td>0.58</td>
</tr>
</tbody>
</table>

TABLE 3

Wald Tests for Own-Region and Inter-Region ¥/$ Volatility Persistence

Dependent variables are in columns with independent variables in rows. Regional volatility variables are: AS, Asia; AE, Asia-Europe overlap; EU, Europe; EA, Europe-America overlap; and AM, America. Additional variables in the regressions not reported in the table include a constant, dummy variables for days of major FX events, and dummies for Mondays and holidays. The table reports Wald coefficient tests for blocks of coefficients representing heat waves (own-region volatility persistence) and meteor showers (inter-regional volatility persistence). Chi-square statistics and associated P-values (in parentheses) are reported for each block of coefficients. For each equation, $R^2$ and p-values of Q-statistics for residual autocorrelation are reported for 5 lags (1 week) and 35 lags (7 weeks).

<table>
<thead>
<tr>
<th>Dependent Regions</th>
<th>AS</th>
<th>AE</th>
<th>EU</th>
<th>EA</th>
<th>AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Regions</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.04)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>AS</td>
<td>42.58</td>
<td>28.31</td>
<td>12.18</td>
<td>8.16</td>
<td>3.55</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.04)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>AE</td>
<td>14.51</td>
<td>17.12</td>
<td>13.36</td>
<td>3.88</td>
<td>8.08</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.27)</td>
<td>(0.04)</td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td>14.30</td>
<td>3.67</td>
<td>9.33</td>
<td>23.77</td>
<td>4.38</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.30)</td>
<td>(0.03)</td>
<td>(0.00)</td>
<td>(0.22)</td>
<td></td>
</tr>
<tr>
<td>EA</td>
<td>11.37</td>
<td>9.66</td>
<td>3.36</td>
<td>0.91</td>
<td>21.93</td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.34)</td>
<td>(0.82)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>11.41</td>
<td>0.88</td>
<td>4.56</td>
<td>34.99</td>
<td>11.98</td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.83)</td>
<td>(0.21)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.58</td>
<td>0.49</td>
<td>0.51</td>
<td>0.53</td>
<td>0.48</td>
</tr>
<tr>
<td>p-value, Q(5)</td>
<td>0.81</td>
<td>0.62</td>
<td>0.98</td>
<td>0.13</td>
<td>0.79</td>
</tr>
<tr>
<td>p-value, Q(35)</td>
<td>0.68</td>
<td>0.30</td>
<td>0.96</td>
<td>0.06</td>
<td>0.69</td>
</tr>
</tbody>
</table>

DM/$ estimation results:

*own-region persistence (heat wave) for all regions
*interregional persistence (meteor showers) for
  AE, EA ⇒ Asia
  EU ⇒ Asia/Europe
  AS, EU, AM ⇒ Europe
  EU, AM ⇒ Europe/America
  AS, AE, EU, EA ⇒ America

¥/$ estimation results:

*own-region persistence (heat wave) for all but EA
*interregional persistence (meteor showers) for
  AE, EU, EA, AM ⇒ Asia
  AS, EU, AM ⇒ Asia/Europe
  AS, EA ⇒ Europe
  AS, AE, AM ⇒ Europe/America
  AS, EA ⇒ America

Regions are different
*more aggregated treatment misses unique effects and might ascribe limited evidence of volatility persistence found here to be a more general, global finding
For economic significance of the spillovers, we simulate the model for the impact of a one-standard-deviation shock to the innovations of volatility in each region on current and future values of itself and other regions.
V. Conclusions

own-region volatility spillovers are more significant economically (larger in magnitude) than inter-regional spillovers

- heat waves are more important than meteor showers

Wald tests and impulse response functions associated with inter-regional spillovers indicate some evidence of responses significantly different from zero for several days, the impulse responses clearly illustrate that the economic significance appears to be slight compared to the own-region spillovers

there are arguments to be made for foreign exchange market shocks taking some time to ripple through the market

- ripples are most significant in a region-specific or home-market context and tend not to spill over to other countries in economically significant magnitudes

the normal functioning of the FX market supports the sources of FX volatility being primarily local: whatever causes a volatility spike in one region today, is related to higher-than-normal volatility in the same region tomorrow

1998: Most volatile year since early 1970s

- Asian crisis, Russian bond default, interventions, near-collapse of LTCM
- Shifting macroeconomic fundamentals
- “Hedge funds and panic trading”
- Yen carry-trade
- Liquidity crunch
- Herding to unwind positions

1998: Laboratory to assess determinants of exchange rates

- Public information via macroeconomic news
- Private information via order flow
Data

• Yen/dollar quotes for 1998

• bid & ask and time stamp to nearest second

• use log mid-price weighted by inverse distance to 5-min. endpoint

• n = 1, 2, ..., 288 obs per day, t = 1, 2, ..., 260 days → 74,880 obs

• delete 21:00 Friday - 21:00 Sunday
Intradaily Patterns

- Returns are random but volatility has predictable components
  - business hours open and close
  - lunch
  - daylight saving time shift
  - scheduled government announcements

Calendar Effects

- Holiday dummies
- Tokyo opening
- Summer U.S. afternoon
- Winter Asian Monday morning
- Friday afternoon in America
- Lunch in Tokyo & Europe
- Day-of-week
Estimation strategy for 5-minute returns:

\[ R_{t,n} = s_{t,n} \cdot \sigma_{t,n} \cdot Z_{t,n} \]

\( \sigma_{t,n} \) is daily volatility factor

\( Z_{t,n} \) is i.i.d. (0,1) innovation

\( s_{t,n} \) is seasonal component
Estimate logarithmic seasonal component \( \ln(S^2_{t,n}) \) using FFF regression:

\[
2 \frac{\ln | R_{t,n} - \bar{R} |}{\hat{\sigma}_t / N^{1/2}} = c + \beta O_{t,n} + \sum_{k=1}^{D} \lambda_k \cdot I_k (t, n) + \delta_{0,1} \frac{n}{N_1} + \delta_{0,2} \frac{n^2}{N_2} \\
+ \sum_{p=1}^{P} \left( \delta_{c,p} \cdot \cos \frac{2\pi p}{N} n + \delta_{s,p} \cdot \sin \frac{2\pi p}{N} n \right) + \varepsilon_{t,n},
\]
Regression Variables:

\( \bar{R} \) = sample mean
\( \hat{\sigma}_t \) = *a priori* estimate of daily volatility component
\( O \) = order flow of large institutions
\( I_k \) = indicator for calendar & news events
\( N_1, N_2 \) = normalizing constants
\( P \) = tuning parameter for expansion order
Macroeconomic Announcements

- 32 U.S. news releases from Reuters
- 33 Japanese news releases from Bloomberg

-due to 5-minute frequency, use 3rd order polynomial and estimate effect of each event “loading onto” the pattern

-reported results for significant announcements

-identified by using each release in turn with separate “all other news” variable

-Employment reports most important

-9 U.S. & 6 Japanese “major announcements”
Intervention Effects

• Dummy variables for:

  - April 10: BOJ supported weak yen

  - June 17: First Clinton Ad. intervention supporting weak yen

  - Despite rumors of intervention in 4th qtr., only 2 actual interventions

  - Positive & significant effect on volatility
Order Flow

- Order flow reveals private info. regarding position switches
- unwinding yen carry-trade learned through trades
- may be orthogonal to public info.

- No market-wide data exist

- U.S. Treasury requires weekly position data from big participants

- purchases & sales of spot, forward, & futures contracts

- Purchases $\rightarrow$ $\uparrow$ volatility  Sales$\rightarrow$ $\downarrow$ volatility

Relative Importance of Components

- Construct forecasts containing day-of-the-week & holiday effects

- Omit or include each of 4 components

- Ascending order of importance, daily cumulative absolute returns
  - calendar, announcement, intervention, & order flow effects

- Ascending order of importance, 5 minute absolute returns
  - with time-varying daily volatility factor
  - order flow, announcements, intervention, & calendar effects

- with constant daily volatility factor
  - announcements, intervention, calendar, & order flow effects
Concluding Remarks

• Independent role for order flow
  • account for announcement, intervention, & calendar effects

• Portfolio shifts responsible for much of 1998 yen volatility

• A step toward moving beyond exchange rate models based on “fundamentals”

• Practitioners have long stated that order flow was major source of price changes

• With lack of transparency & asymmetrically-informed traders we might expect that order flow contains independent info.

Reference: http://public.asu.edu/~mmelvin/
D. Stop-Loss Orders and Price Cascades in Currency Markets

Price cascades, discontinuous gapping, and other forms of massive and abrupt exchange rate changes may be caused by stop-loss orders.

Stop-loss order: order to buy (or sell) once the exchange rate rises (falls) to a certain level
- positive feedback trading

Take-profit order: order to buy (or sell) once the exchange rate falls (rises) to a certain level
- negative feedback trading

Both differ from limit orders in that they are executed as market orders or “at best” orders conditional on the exchange rate reaching a threshold.

Rational, uninformed agents could misinterpret stop-loss trading as informed agent activity and intensify price cascades.
SL & TP cluster at round numbers

- Executed SL buy (sell) orders tend to cluster just above (below) round numbers
- Executed TP orders tend to cluster at rates ending in 00

Methodology: examine exchange rates around round numbers

- DEM/USD, JPY/USD, USD/GBP
- NY trading hours 9:00-16:00
- Round number ends in 00 or 50
  - DEM/USD = 1.4950 or JPY/USD = 123.50

2 subsamples
- Rates cross round number
  - Above (below) 15 minutes after reaching rate from below (above)
- Rates reverse at round number
Test if average signed log exchange rate change after crossing round numbers exceeds corresponding average change for arbitrary numbers

Bootstrap: examine 10,000 sets of 30 arbitrarily chosen rates assuming round numbers are not special

- Set \( A = \text{max} - \alpha(\text{range}) \)
  - \( \text{max} = \) maximum rate for relevant sample period
  - \( \text{range} = \) range over the period
  - \( \alpha = \) random number chosen from uniform distribution over unit interval

- Split sample into 58 intervals of 10 consecutive trading days
  - Compare avg signed change after crossing round number with that found after crossing the arbitrary numbers
  - Null hypothesis assigns prob = .5 to each, so Bernoulli trial with prob=.5
  - Alternative hypothesis has greater rate change after crossing round numbers
  - Combined trials has binomial dist with parameters \((0.5,n)\) where \(n\) is number of 10-day intervals in which both round and arbitrary numbers are reached at least once
  - Data support alternative: round numbers matter
Comment: Since the result is not conditioned explicitly on SLs, maybe it is just some technical trading trigger rather than trend propagation by SLs that moves rates more after crossing round numbers??

Test TP order implications by examining proportion of times rates reverse course upon reaching a round number (come within 0.01%)
- Reverse course means rate has not passed round number 15 minutes after reaching it
- Key stat is number of 10-day intervals in which reversal frequency exceeds avg reversal frequency for arbitrary numbers
- Null is no difference
- Alternative is that more frequent reversal at round numbers—data support this for DEM/USD and JPY/USD, but not USD/GBP

Comment: Since the result is not conditioned explicitly on TPs, maybe it is just some technical trading trigger rather than trend reversal by TPs??

Test if SL rate effects exceed TP rate effects by examining if rate changes more after crossing round numbers than reversing
- Comment: still not directly testing SL or TP effects
- Data support crossing effects exceed reversal effects
An alternative proposal for this research, a sort of “runs” test:

Specify returns as 2 types:

\[ R_t = 1 \text{ if } d \ln S_t > 0 \]
\[ R_t = 0 \text{ if } d \ln S_t \leq 0 \]

assume 2-state Markov Chain:

\[
\begin{align*}
P_{11} &= \text{prob}[R_{t+1} = 1 | R_t = 1] \\
P_{01} &= \text{prob}[R_{t+1} = 0 | R_t = 1] \\
P_{10} &= \text{prob}[R_{t+1} = 1 | R_t = 0] \\
P_{00} &= \text{prob}[R_{t+1} = 0 | R_t = 0]
\end{align*}
\]

runs and reversals reflected in probabilities

include endogenous regime switching:

\[ P_{ii,t} = \Phi[\alpha_{ii} + \beta_{ii}] X_t \]

where \( i \in \{0,1\} \), \( \Phi[] \) is the cumulative normal df, and \( X \) is a vector of variables including executed SLs and TPs.

Test whether the presence of SLs and TPs are associated with runs and reversals as reflected in estimated state probs
